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ERNEST E. THUM, EDITOR

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STEEL CARTRIDGE CASES FOR ARTILLERY AMMUNITION

BY HAROLD R. TURNER
Lieutenant Colonel, Ordnance Dept., United States Army

THE USE OF BRASS as material for cartridge cases for artillery ammunition is as old as the earliest weapon using a cartridge case. This is readily understandable when we recognize that the art of making small articles of brass is an old one, whereas the art of making comparable articles of steel is comparatively new.

All of us Americans from our earliest days in school were taught and believed that, with the exception of a few materials, the resources of our country were adequate to meet the most extraordinary demands. None of us, however, in the wildest flights of imagination, conceived the magnitude of the present world conflict nor did we dream that warfare would become so completely and so terribly mechanized. Never did we contemplate so many armored vehicles, each mounting not one, but several weapons. Never did we contemplate so many thousands of airplanes, each carrying many guns. The quantities of ammunition required are measured in almost astronomical figures, for it has been estimated that in this second World War we are producing in the United States as much ammunition in five months as was expended by American troops in the entire first World War, and the rate of production is ever increasing.

When we stop to consider that copper is the vital element in the production of electrical equipment and of radio, and even of ships, guns, airplanes, trucks and ammunition, and we simultaneously consider the enormous quantities of these things that must be made, it is perhaps not quite so surprising that even the resources of *our* nation are inadequate to provide the necessary metal.

When the impending shortage of copper became evident, studies were made to determine where the large expenditures were being made and each case analyzed to determine whether the item could be manufactured practicably from some substitute and still entirely meet the rigid functional requirements. This analysis very quickly looked at cartridge cases for artillery ammunition, because here the expenditure of copper in the form of 70-30 brass was enormous. The question was immediately raised as to whether it were possible to make steel cartridge cases which would completely fill the functional requirements and be capable of manufacture under mass production methods.

Such manufacture, or at least its contemplation, was by no means new. One small company in the United States made a very few steel cartridge cases in the early days of World War I but, unfortunately, this company ceased to exist many years ago and much of the record of its work was lost. However, certain basic facts were available through the U. S. Patent Office and other channels. The records of World

War I show that the Germans had made certain cartridge cases from steel but these were packed in containers with a warning that they must not be used in barrage fire. This caution pointed immediately to the probability that extraction of these cases from the weapons was poor, and that high rates of fire could not be maintained. Through the intervening years attempts to make steel cartridge cases appeared, but at no time was the urge behind the development as great as currently exists, because no one imagined a shortage of brass.

When this shortage did occur, the ordnance engineers of the Army made an exhaustive search of all available information on the subject and were somewhat appalled at how little really was known. It will be my purpose to present in a broad fashion the solution to this problem.

In order that you may have a fairly clear picture of the actual problem, it is important that you understand what a cartridge case actually is and what it does. The popular conception seems to be that a cartridge case is little more than a can of somewhat peculiar shape. Actually, it has a rather complex function.

First, it is a container to hold the propellent powder which causes the projectile to leave the gun at an extremely high rate of speed.

Second, it is the support for the primer element whose function it is to ignite the propellent powder. This element must be supported properly and accurately in the head of the cartridge case.

Third, the cartridge case is a support for the projectile which is rigidly installed in the mouth of the cartridge case.

Fourth, the cartridge case acts as a valve which operates at an extremely high rate of speed to provide a complete seal in the breech of the gun, thus preventing the gases from blowing through the breech of the gun, so that their entire energy may be expended in moving the projectile. Since the phenomena which occur at the instant of firing involve extremely high pressure built up at exceedingly high rates, the comparatively simple looking can known as a cartridge case becomes, in fact, an extremely complicated device.

Chicago Chapter should be complimented for getting Harold Turner to talk before its December meeting on steel cartridge cases. No one could do it better, for he has been actively pressing the development since late 1941. Previously the Censor would permit little except generalities to be published, although so many ASMembers have participated in the program that details are an open secret. Lt-Col. Turner praises American industry for the achievement; ASMembers would say that much credit should rebound to him.

In attacking the problem of producing steel cartridge cases, three avenues of approach were explored: First was the use of methods which assembled two or more parts to make the finished case; second were processes which used hot working for the early operations; third were cold working methods.

There were many problems to be considered apart from the purely technological questions which had to be weighed fully in arriving at the ultimate decisions. Since these particular problems are common to all three methods outlined above, it would be well to point them out briefly.

A large and active industry was already engaged in the manufacture of brass cartridge cases. The facilities existing within these establishments must be used if possible, since their complete replacement would be unsound economically and the rapid procurement of equipment almost impossible.

The material used had to be one which required the minimum amount of strategic alloying elements. In other words, unless experience proved the task impracticable of solution without chromium, nickel, and other alloys, it was essential that the steel be of comparatively simple analysis with even manganese reduced to the lowest possible. Third, the cost of the process developed should be comparable to the manufacture of brass cartridge cases — theoretically, the difference should closely approach the difference in cost of the basic materials.

It is not possible at this time to catalog the other limiting conditions which had to be faced and which were born entirely of a war economy. So it must be borne in mind that *many* factors weighed heavily in the final decision.

Since the chief interest is in the final process selected, I will describe only briefly the two which were discarded.

Multi-Part Cases

In the research which preceded actual production we found many references to efforts to make steel cases by assembling two or more parts. In general, all this work followed one common pattern: A head was produced, with the necessary conformations in this region, either by forging and machining or by machining from bar stock. The body of the case was made from tubing either drawn or welded. The methods devised for joining the tubular wall to the base were extremely ingenious, sometimes simple, sometimes complicated. Unfortunately, with a very few exceptions they were uniformly unsatisfactory in the guns.

There is little question that satisfactory steel cartridge cases could be made by the assembly of several parts. To do so, however, would involve the procurement of tremendous quantities of new and, in many cases, highly special machinery. It would involve the development of techniques whch would take a long time and be very costly. It was early established that rather drastic heat treatment would be necessary if adequate physical properties were to be attained, and heat treatment is in itself an art and, if used, would require a very elaborate training program.

Therefore, this method was discarded, not because it was impossible but because the time available to accomplish the conversion did not permit the required research.

Hot Forging

The second group of processes involved the conversion of disks or slugs of steel into a cup by hot forging. By using a steel rich in the alloying elements, a small lot of steel cartridge cases was made in this way. They were highly successful. However, to utilize the process necessitated large quantities of expensive and special machinery. Further, it entailed the education of a multitude of manufacturers in the highly technical art of working steel hot, and avoiding the multitude of hazards and deteriorations which accompany the working of steel at high temperatures.

At the present time, there are two manufacturers actually producing steel cases using hot forging methods in the early operations, and using steel which is simple in its analysis. Experience to date with these cases is not completely satisfactory, nor has sufficient evidence reached us as yet to indicate that such a process is going to be highly successful — even in the hands of these two manufacturers whose peacetime experience over many years has given them a tremendous "know how" in the handling of steel at high temperature. There are other reasons, which unfortunately cannot be discussed, upon which the ultimate decision to avoid hot forging was based.

Cases Made by Cold Work

The great prosperity our automotive industry has enjoyed, and the tremendous advances it has made as a business are, to a great degree, based on the ability of American fabricators to draw steel. By virtue of many years of development in its production of complicated shapes from steel sheets, the steel industry has also developed the art of making suitable steel. Drawing on the experience thus acquired it was possible for us to procure the steel which experimentation indicated would do the job with minimum demands on the dwindling stock of strategic materials.

The Ordnance Department did not presume to carry on this development alone but rather threw the entire burden on that portion of American industry whose experience best fitted it for the task. To this end, the Ordnance Department invited the man who enjoyed the reputation of being one of the best in the field of steel drawing to come to Frankford Arsenal and asked him whether or not he felt it were possible to produce from steel the counterpart of a brass case. Interestingly enough, his immediate reactions were negative because the contours were complex, the thickness of the metal varied widely and abruptly, the diameter was small when compared to the length, and the physical requirements were far beyond anything that industry had had ever before been called upon to make.

Nevertheless, with a typically American attitude, he returned to his plant to try. As a cartridge case, the original trial was a complete failure but it did establish that steel *could* be drawn with comparatively simple tools into the required conformations. Having established that basic fact, there was sufficient hope to warrant going ahead.

With the meager information so far obtained, one of the steel companies considered the metallurgical problems. A great number of small heats of steel were made with a multi-

tude of variations in the chemistry, condition, and treatment, and as each trial was run, some crumb of information was accumulated. After a few weeks of this effort, it was evident that the job could be done, in an entirely practical fashion and on existing equipment.

At this stage of the development, the Ordnance Department invited almost every manufacturer who had equipment and experience in the field of deep drawing steel to participate in the development, and experimental contracts for the development of tools and the production of a small number of steel cartridge cases were awarded to some 50 or 60 manufacturers. To each of these the Ordnance Department is proud to pay tribute, for each contributed something and it is the accumulation of knowledge that has made the progress we now enjoy.

Critical Section Near Base

It is regrettable that, because of this war, we cannot at this time disclose the intimate details. However, I can tell you some of the broader phases of the problem and cite in general terms the methods which finally solved the difficulties.

For example, it was found that in the tubular section of a cartridge case, particularly in the region adjacent to the thick base, the tensile properties which were entirely adequate in brass would fail completely in steel. Those who are familiar with the basic characteristics of the two alloys will not find that difficult to understand. The solution of the difficulties in this area necessitated the procurement of physical characteristics in the steel nearly double those required in brass.

Serious difficulties were encountered in the thick base portion of the case in an effort to make this region stand up against the terrific loads generated during firing. It was early discovered that steel behaves vastly differently, in a heading press for example, than brass, and the process which is satisfactory for brass is completely unusable. Months of the most tedious experimentation went on to solve this one problem but when the solution was reached (only last June) the longest single step towards the successful conclusion of the program had been taken.

With this out of the way, more time could be spent on the draw technique. The early opinion was that, in the change from brass to steel, press requirements would go up two or three times. Careful investigation disclosed that for a good draw operation, the press capacity requirements went up only 10 to 15%. It was found that the draw speed must be reduced in the order of 15 to 20%. It has long been a more-or-less accepted rule that reduction of area by drawing cylindrical shapes from steel should not greatly exceed 35% per operation. Therefore, it often became necessary to add one or more operations to the conventional brass drawing program. Additional draw presses had to be bought and installed, but otherwise there was no great difficulty.

With the basic problems well under control, it became necessary to attack a multitude of detail problems in order to reach quantity production. The use of draw rings other than those made of tungsten carbide or similar material was found quite impractical for two reasons. First, the finest steel dies obtainable would gall and pick up metal and seriously scratch the work. Second, their life was extremely brief. Many questions concerning the entry angle to the die, the area of contact, method of support, and the lubrication had to be solved. The exact conformation of the draw punches and types of material to be used also were questions of no small magnitude. Here again we regret that many of these points cannot be discussed in detail, for obvious reasons, but the data will be made available to American industry when the war is over.

As has been indicated earlier, much time and study was put into the questions surrounding heat treatment. Many interesting phenomena have been observed. For example, one comparatively little known property of steel assumed importance, and that is that in stress-relieving cold worked steel an actual gain in physical properties is observed, if the temperature falls within a limited range. This improvement varies as a function of the amount of cold work. It proved to be of great benefit in the ultimate solution of some of our difficulties.

It was further discovered that while the steel blanks must be completely or nearly completely spheroidized, comparatively little difference appeared in the later operations if the steel was in a pearlitic condition. This was most important, since it made available a great number of existing annealing furnaces. Many long discussions were held as to whether or not bright annealing was necessary, or whether other types of furnaces were adequate. Here again it was found that there was little or no

difference in the end product if proper recognition was given to the results obtained in each type of furnace.

Looking briefly at the subject of lubricants, it can be said that practically everything on the market was tried and a number of new products were developed. It is interesting to note that a number of the standard products were found very satisfactory. It was further discovered that the degree of satisfactoriness varied widely in different plants, indicating that special conditions are set up by types of equipment and other minor factors which are difficult to identify.

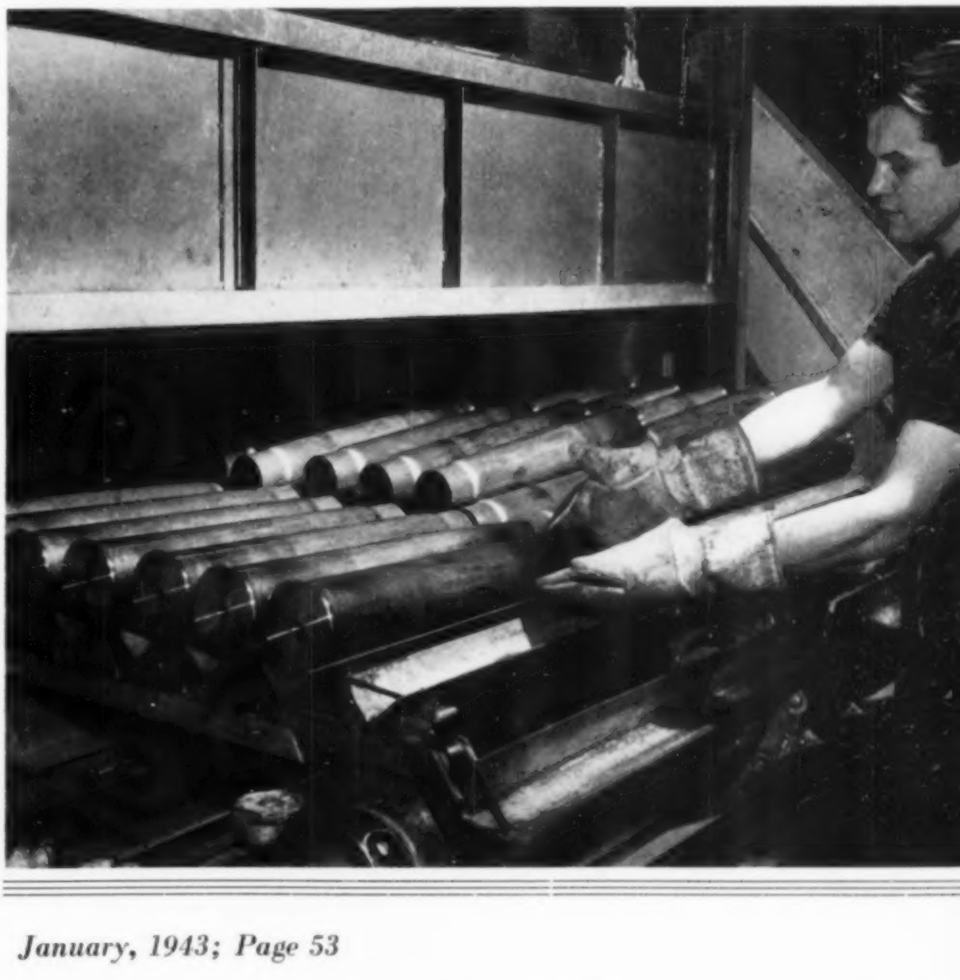
The problem of rust protection of the finished steel cases had been and is one presenting great difficulty. In the early stages it was thought that plating with copper, zinc, chromium, even silver might be the proper solution, and that section of American industry devoted to plating and plating materials did some brilliant work in developing coatings and methods of application. Unfortunately, however, our supply of critical metals required by this procedure was too small and the use of protective plating had to be abandoned. The present process uses phenolic varnishes of very high quality, applied in unusually thin coats and cured with great care. A finish of this type on an item such as the cartridge case demands far more than is customarily required of a paint. It must withstand the action of strong solvents because of the reactions with burning powder. This is in addition to a severe requirement for protection against abrasion and corrosion. Manufacturers of paint in the United States have again risen to the occasion and provided materials which are very successful.

Reviewing very briefly the development of steel cartridge cases, we find that the steel industry has, by virtue of much hard and discouraging work, succeeded in producing steel with the necessary qualities; that the industries of our country which have been engaged in the processing of steel, have drawn from their experience and by continuous work broadened their knowledge and accomplished a difficult task of fabrication. The manufacturers of finishes have, by the same efforts, made their most valuable contribution. The brass industry has cooperated in a most satisfactory fashion, and has applied much of the knowledge acquired from years of working brass, and has most patriotically accepted a situation which must be somewhat repugnant to them. The brass men have made most valuable contributions.

The problem of manufacturing the cartridge cases for artillery ammunition for steel has been solved. The solution has been accomplished by nearly 18 months of the most strenuous effort on the part of many branches of American industry.

Again the Ordnance Department of the United States Army is proud to pay tribute to American Industry for its cooperation in the solution of one of those problems labeled "It can't be done"!

Precise Temperature Control During Stress Relief Enhances Physical Properties of Finished Case. Female labor has also entered the heat treat! Photo by Palmer for Office for Emergency Management



WAR PRODUCTS CONSULTATION:

TEMPORARY SET IN HEAVY SPRINGS

The Problem

Posed by an Ordnance Inspector

We are assembling into heavy gun mounts a volute spring furnished by one of the leading manufacturers. It is coiled from a ½x1½-in. bar and its free height after heat treatment, cold setting and delivery is about 24 in. It passes all acceptance tests, shows no permanent set after rapid or slow loads, and appears to be a very well-made article; however, we are bothered by a variable amount of set after it is pressed nearly closed and kept that way for 24 hr. On being released, the spring never regains its original height (in one case the shortening was well over 1 in.) but does come back if the spring is given a few moderate loadings or even dropped on the floor a couple of times.

Confining our attention to this matter of quasi-permanent set after long-time heavy loading, we would like to know three things:

(a) What change in manufacture could be considered so as to avoid it?

(b) Is there any technical or scientific explanation of the action?

(c) Does the phenomenon indicate any chance of short life in a gun recoil mechanism?

Suggested Answers

Possible Change in Manufacture

By Spring Maker

This spring was doubtless coiled hot on a mandrel to a free height in excess of the design requirement. It is good manufacturing practice to reheat for a quench, draw to the specified hardness, and then cold set the spring to the solid condition, and when the load is removed, the free height is diminished. (Rightly or wrongly, the spring maker's name for the cause of this is "hysteresis of the material".) This process is repeated, if necessary, until the free height reaches a constant figure equal to the desired length.

Cold setting in the shop is done in several seconds, or a few minutes at most. If an additional cold set is made and held for a long period, say 24 hr., either in the shop or on the test bench, there will be further deformation due to hysteresis, and hence further loss of free height. It is a phenomenon allied to creep* — that is, a gradual slow yielding and recovery of the metal over a long period of time, when stressed below the limit of plastic deformation (permanent set). The difficulty with the spring under discussion (if it is a fault) is not due to faulty heat treatment (although such treatment will magnify the trouble), but is primarily due to the high solid stresses in a test that is unduly severe, and which probably has little relation to the desired performance in service.

The higher the stress to which the spring is subjected, the greater will be this temporary shortening. It would be minimized by reducing the stresses where possible and by making sure of a surface free from decarburization. It can be further minimized by heat treating to as high an elastic limit as possible. If the spring is made of silico-manganese or chromium-vanadium steel, you should be able to heat treat it to

*Editor's Note: This should not be thought of in the same terms as when the word is used to represent slow extension under load at elevated temperatures. It is rather that portion of the *elastic* action of the steel which takes time to become evident; true "creep", in the spring maker's sense, is therefore exactly recoverable by "relaxation", if time be given.

a Rockwell as high as C-52. This will give you a higher elastic limit than by a more normal heat treatment, and it might be satisfactory for gun springs, which have a limited life.

There is one other treatment which is effective on heavy springs of silico-manganese steel. The springs could be coiled to a considerable amount longer than normal, say at least 10% over length, and after heat treatment heat them to at least 500° F. and compress while hot. If this heat gives too great a loss in free length, then the temperature could be slightly reduced, or vice versa.

Reason for Quasi-Set

By Research Engineer

The phenomenon of loss in height of the spring when compressed for a period of time is tied up with the creep* of the material under load at room temperature, and the opposite of creep, namely "relaxation". Experience shows that this relaxation may occur at ordinary as well as at elevated temperatures if the stresses are high enough.

Any steel spring kept deformed for a length of time acquires a bias in the direction of the last load, caused by what is known as "primary creep" of the metal. This primary creep is usually small in highly heat treated steel such as used for watch springs or spring scales. However, no steel is free from this effect and the higher the load the greater the amount of deflection of this type. Usually the load tolerances will be broad enough to cover the effect, and in sharp release after a short load the spring tends to over-travel and it comes back very close to its original length.

The reason why this loss in height of the spring due to creep under load is not recovered immediately on releasing it is that relaxation takes time. The fact that there is a *tendency* to regain the original height when the springs are flexed or dropped on the floor is probably due to the combination of vibratory and residual stresses present. These residual stresses are set up on initial compression, or on cold setting the spring beyond the elastic limit, and are in such a direction as to subtract from the load stress when the spring is again compressed. However, under vibration conditions such as would occur when the spring is dropped on the floor, stresses of opposite sign to the load stress are set up. These stresses are in such a direction as to add to the residual stresses, and under such conditions a peak stress beyond the yield stress, but in an opposite direction to the load stress, may occur. This is particularly true since stressing a material beyond the yield point in one direction tends to lower the yield point for stresses in the opposite direction (the Bauschinger effect).

The net result is that vibration tends to reduce the residual stresses, which in turn means that the spring tends to regain its original height.

Test Indicates a Tough Spring

By Mechanical Expert

This effect which is worrying the inspector should have no bearing whatever on the use of the spring in a gun recoil mechanism, as the service loads are not maintained long enough for primary creep to occur. This conclusion can be fortified by considering whether the spring would be a better spring if it were treated so as to minimize the effect.

The heat treatment which would show the least primary creep would probably produce a totally sorbitic or martensitic structure free of residual austenite. (A small amount of residual austenite accentuates primary creep, as is well known to manufacturers of clock and watch springs and makers of precision springs for balances and scientific instruments.)

If the job were mine, I would look upon this behavior as favorable rather than otherwise, for it is also commonly considered that material containing residual austenite and exhibiting primary creep is less notch-sensitive than a more truly elastic metal. If these springs are behaving properly in service, I certainly would not change the steel or its treatment.

The Solution

Reported by the Ordnance Inspector

The notes, especially by the mechanical expert, are comforting. Our experience in the railroad industry has shown that heavy springs have been vastly improved after modernizing the manufacturing and heat treating operations, and so we first turned attention to those details when confronted by a phenomenon in these gun mount springs that was new to us. We find that the "set" after long loading is truly only temporary, and we are especially glad to find that if the steel relaxed more quickly it would probably be more brittle than desirable.

Standard solders, which have been inherited from the days when plumbers worked almost exclusively with plumbum pipe, and "wiped" the joint, are notoriously extravagant in tin. The wiped joint needs a wide mushy range during solidification, and this is a property of high tin-lead alloys; nevertheless most solder now is used in exceedingly thin film, and shear strength and alloying properties are paramount in them. Many suitable solders for such thin joints, low in tin, are now available. This timely article describes a good solder that contains no tin at all.

A NEW SOFT SOLDER; LEAD-ARSENIC-ANTIMONY ALLOY

By R. L. DOWDELL, M. E. FINE, J. F. ELLIOTT and I. C. MATTSON
Division of Metallography, University of Minnesota

THIS INVESTIGATION to discover a low cost, tin-less solder was undertaken because of our present tin shortage and also because a permanent market exists for a low cost solder.

For a great many years tin-lead alloys have been the standard solders, bought to engineering specifications. These alloys combine low melting point, strong joint strength, high wetting power, and high spreading power. For general soldering the 50-50 tin-lead solder has been the most popular; other alloys than those of tin and lead have been used only for very special purposes. In recent months, however, the use of solders containing more than 30% tin has been prohibited in many former applications.

Although there has been a great deal of research in this field lately, no entirely satisfactory tin-less solder has been developed. Considerable publicity has been given to an alloy of 97.5% lead and 2.5% silver; however, the cost of this alloy is relatively high, its melting point is too high, it oxidizes rapidly at its melting point, and its wetability is too poor for rapid soldering.

Several low tin alloys have been recommended; one in particular described by S. Turkis and A. A. Smith ("Some Properties of Low Tin Solders Containing Silver and Bismuth", in *Metals & Alloys* for March 1942) contains 78.5% lead, 15% tin, 5% bismuth, and 1.5% silver. It handles much like the 30% tin, 70% lead solder, but relieves the tin shortage only slightly; besides, it has a wide solidification range which is often objectionable for fast soldering. Since several articles have recently been written about substitute solders, there is no need to review the literature here. The reader is referred to the articles by F. N. Rhines and W. A. Anderson on "Substitute Solders" in *Metals & Alloys* for November 1941, and H. W. Gillett's report to W.P.B. for the National Academy of Sciences, abstracted in *Metal Progress* for May 1942.

The data presented in this paper prove that an alloy of 87.5% lead, 0.5% arsenic, and 12% antimony, besides having low cost, has better "solderability" on steel and tin plate than any tin-less solder in present use that the authors are aware of.

Development of the Solder

Soldering with pure lead is difficult, mainly because of its relatively high melting point, and also because it oxidizes so readily immediately after melting. Arsenic, if added to lead, acts as a flux and helps prevent oxidation, as demonstrated in the manufacture of round shot by dropping molten alloy down a shot tower. With this in mind a series of lead-arsenic alloys was tried as solders, and it was found that they oxidize less, flow better than pure lead, and give a harder joint because of a fine grain size. However, the melting point is too high for easy manipulation. The wetability on tin plate is satisfactory, but on black iron it is poor. Schumacher and Phipps had already reported that 0.1% arsenic added to tin-lead wiping solders (37¼% tin) cut the oxidation

Table I — Composition and Properties of Lead-Arsenic Alloys as Solders

Analysis (a)		Melting Range (b)		Hardness (c)	Lap Joint Strength
% Pb	% As	Liquid	Solid		
99.98	....	621° F.	621° F.	4.1	
99.75	0.25	615	550	5.5	
99.5	0.5	609	550	7.7	
99.0	1.0	597	550	7.7	5100 psi.
98.5	1.5	585	550	7.5	
98.0	2.0	574	550	9.2	
97.4	2.6	565	550	10.2	
97.0	3.0	550	550	9.1	

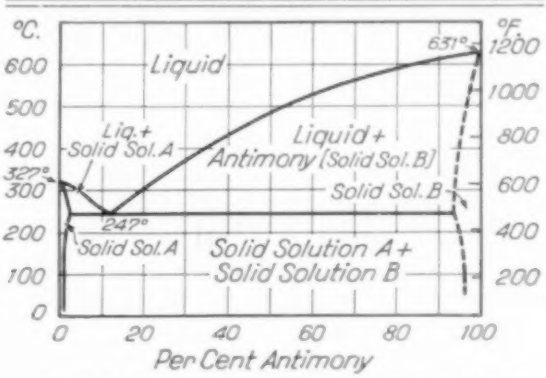
(a) Alloys were made up to this composition but not analyzed.

(b) Melting points from the phase diagram of Heike, International *Journal* of Metallography, 1914.

(c) Hardness is with Vickers diamond pyramid and 5 kg. load; average of five readings.

in the solder pot to a fraction and gave a much finer grained joint (*Metals & Alloys*, March 1940).

For our further investigation a series of alloys varying from 0.25 to 3.0% arsenic was made by melting a lead-arsenic hardener (containing 23.27% arsenic) with electrolytic lead of 99.98% purity under a cover of molten zinc chloride. Alloys up to 1.0% arsenic were also made with a hardener containing 1% arsenic. The compositions of these alloys and some of their properties are given in Table I.



Lead-Antimony Constitutional Diagram; Metals Handbook, 1939 Edition, P. 1516

The best combination of properties in the series was obtained with 0.5 to 1% arsenic. A higher arsenic content gave a dirtier solder. In soldering, a dark brown slag appeared, most likely a mixture of $PbO\text{-}As_2O_3$, which aided in removing oxidized lead, but with high arsenic too much of this slag formed. At the high temperature necessary for soldering, the solders oxidized readily on the soldering iron. This increased as the arsenic was increased above 1.0%.

In an effort to lower the melting point antimony was added to arsenical lead, and it was found that solderability was considerably increased. A series of alloys containing antimony and arsenic was then made by adding antimony to the proper mixtures of lead and arsenical lead. In this work, molten zinc chloride was again used as a cover.

As shown in the lead-antimony constitutional diagram, antimony up to 13% lowers the melting point. The solderability of the alloys was also found to increase with increase in antimony up to about 12%.

The composition and some properties of the higher antimony alloys, 50-50 tin-lead solder, and American Smelting & Refining Co.'s tin-lead-bismuth-silver solder are given in Table II. Since the solderability increased with antimony, the lower antimony alloys are not given. The mechanical properties of the alloys were obtained from castings 0.5 in. thick which were rolled to 0.040 in. thick and annealed at 390° F. for 3 hr.; averages of five tensile tests made from each lot are shown.

The alloy of 0.5% arsenic, 12% antimony, balance lead, has the highest lap-joint strength. Although the alloy with 1.5% arsenic has greater tensile strength it is quite brittle and gave a weaker joint. The joint made with 50-50 tin-lead approached this lead-arsenic-antimony alloy closest.

Table II — Composition and Properties of Lead-Arsenic-Antimony Solders

Composition			Melting Range		Tensile Properties			Hardness (b)	Lap Strength (c)
Pb	As	Sb	Liquid	Solid	Strength	Elongation (a)	Reduction of Area		
100	...	..	621° F.	621° F.	2340 psi.	43.6%	100%	4.1	....
89.5	0.5	10	492	476	5860	28.0	55.3	18.0	7100 lb.
89.0	1.0	10	480	469	6110	13.6	17.6	19.8	6100
88.5	1.5	10	482	469	6260	9.4	11.9	19.7	6000
87.5	0.5	12	478	476	6160	35.8	36.9	18.4	8300
50	..	(d)	421	358	5520	101.0	93.8	12.3	8100
78.5	15	(e)	507	...	5970	19.6	36.6	12.7	6200

(a) 1.5-in. gage length.

(b) Vickers diamond pyramid with 5 kg. load; average of four readings.

(c) Details described in text.

(d) 50% tin.

(e) 5% bismuth, 1.5% silver.

An alloy of 12% antimony with no arsenic was tried, but it was found that the absence of arsenic increased the amount of oxidation and decreased the flowability.

Of all the alloys made and tested, the alloy with 0.5% arsenic and 12% antimony behaved the best. It was the most fluid, had the lowest melting point, wet black steel the best, and gave the strongest joint. This analysis is near the antimony-lead eutectic, so it has a very short solidification range.

In using a copper soldering tool this alloy will not wet the tool as well as the tin-lead solder because of the formation of a copper-antimony compound. An addition of up to 15% tin raised the melting point slightly and gave brittle joints. By proper soldering technique, which will be described later, this handicap was overcome, so no tin was used.

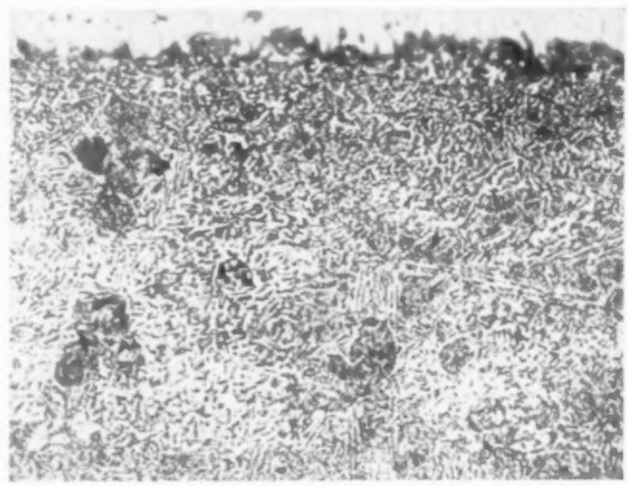
Adjoining is a photomicrograph at 500 diameters of a steel lap joint soldered with an alloy of 0.5% arsenic, 12% antimony, balance lead. The roundish darker areas are dendrites of lead-rich solid solution that solidified first; the major portion is a eutectic of antimony and lead. Arsenic cannot be seen as a separate phase; it probably is in the eutectic.

Comparison of Properties

Because the alloy of 0.5% arsenic, 12% antimony, and 87.5% lead showed great promise as a solder, its properties were compared with those of other substitute solders, and also tin-lead solders, as given in Table III. Alloys No. 2, 3, 5, and 7 were bought, while the others were made by us.

In comparing these solders, joints made with both soldering iron and oxy-acetylene torch were used. Soldering was tried on black steel, tin plate, galvanized steel, copper, and brass. Tests consisted of *(a)* observing the solderability of the different solders and *(b)* making and pulling of lap joints.

Lap joints on bare steel were made with both soldering iron and torch. The strips used were $\frac{1}{2}\times\frac{1}{16}\times2$ in. The strips were first pickled, then fluxed with hydrochloric acid cut with zinc. Ends were tinned, and then the soldered joints were made by overlapping these ends about $\frac{1}{4}$ in. Heat was applied until the two pieces were soldered together and the joint held firmly together while it cooled. A photograph is reproduced on the opposite page.



Lap Joint of Steel Strips Joined With Solder Composed of 0.5% Arsenic, 12% Antimony, Balance Lead. Etched in 1 part glacial acetic acid, 9 parts alcohol. Magnified 500 diameters

The joints were then pulled in tension in an Amsler testing machine. Strengths are given in Table III. Only sound joints were used in calculating the average, and each value is an average of five joints. (This same technique was used for the joint strengths listed in Table II.)

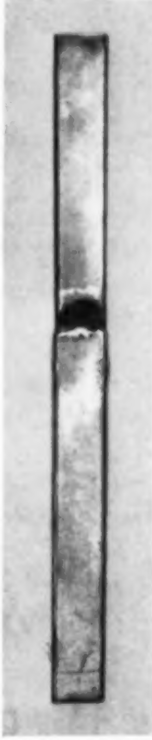
Solder No. 2 has fairly good flowability but its adherence to steel is only fair. (In testing the lap

Table III — Comparison of Soft Solders

No. *(a)*	Chemical Analysis						Melting Range		Shear Strength *(b)*	Solderability with Torch			Cost, 100 Lb.
	Pb	Sn	As	Sb	Ag	Others	Liquid	Solid		Fe	Cu	Zn	
1	87.5	.....	0.5	12.0	....	....	478° F.	476° F.	8300 psi.	good	poor	fair	$10.00
2	97.5	0.75	...	....	1.75	....	580	550	5800	fair	fair	fair	28.50
3	97.0	.....	...	1.0	2.00	Tr P	590	575	5800	fair	fair	fair	26.50
4	97.25	.....	...	....	2.50	0.25 Cu	590	576	4800	fair	fair	fair	....
5	78.5	15.00	...	....	1.50	5.0 Bi	507	...	6200	good	fair	fair	31.25
6	99.0	.....	1.0	....	....	....	597	550	5100	poor	bad	bad	9.00
7	50.0	50.00	...	....	....	....	421	358	8100	all very good			31.60

(a) Source:
No. 1. Authors' solder.
No. 2. National Lead Co. solder No. 580, recommended as "best substitute solder".
No. 3. North American Smelting Co. "Victory Solder".
No. 4. Silberstein's alloy (Westinghouse Alloy No. 35) used for high temperature electrical joints.
No. 5. American Smelting & Refining Co. alloy.
No. 7. Ordinary half-and-half solder.
(b) Lap joints with steel; average of five.

Typical Lap Joint; Full Size



joints several of the specimens failed between solder and steel rather than through the solder itself.) Soldering No. 2 with a copper soldering iron is difficult because at the high soldering temperature this alloy oxidizes very readily on the iron. In soldering on tin plate the solder tends to run away from the joint causing what is known as "cold edge". (Solder tends to build up at edges of solder line, the actual joint being in a valley.) In a butt joint, if the two pieces to be soldered together are a slight distance apart the solder bridges this gap with difficulty. The flowability of the solder on brass and copper was better than on bare steel and was best on tin plate. Because of the high temperature required, torch soldering was easier than with an iron.

Number 3 alloy behaves much like No. 2; No. 4 behaves in a similar manner also. Its joint strength was weaker (4800 psi.) perhaps because in making the alloy the solder may have become oxidized. No. 5 alloy was found to behave much like a 30 tin, 70 lead solder; their liquidus temperatures are fairly close. With a torch this alloy shows good flowability on copper and brass but not quite so good on steel. Its surface has a rather frosty appearance. In using a torch, joints made with solder No. 5 tend to pull themselves apart on freezing.

With the silver solders No. 2 to 5 — except the last which is an intermediate solder having 15% tin — an active flux like zinc chloride or orthophosphoric acid is required because of the high temperatures of application (550 to 650° F.). Ordinary solder with high tin does not oxidize nearly so much at this high temperature. Rosin and alcohol fluxes are not satisfactory.

The No. 6 alloy oxidized more rapidly than the silver solders. Soldering on copper, brass, and galvanized iron was more difficult than on mild steel. It wets mild steel but does not flow readily; the solder must be pushed around. The flowability on tin plate, however, is satisfactory. Excess zinc chloride was found to be objectionable. Because the solder had to be pushed to spread it on bare steel, soldering with an iron was found to be easier than with a torch.

The alloy of 12% antimony, 0.5% arsenic, balance lead (No. 1), soldered bare mild steel with little difficulty. It wet the steel readily, and with an acid flux, like cut hydrochloric acid, the solder followed the flux well and soldered quite rapidly. Shear strength of lap joints made on steel was 8300 psi., while the 50% tin, 50% lead soldered joint gave 8100 psi. The solderability on tin plate and steel was superior to any other tinless solder tried, and the appearance of the joint was also better.

This alloy is not recommended for copper, brass, or galvanized iron, since with these it has almost no adherence or flowability.

Special Soldering Technique

Because the alloy of 12% antimony, 0.5% arsenic, balance lead, handles differently than 50-50 solder some differences in technique must be observed. In the first place its melting point is higher. This necessitates heating the soldering iron hotter or using a hotter flame to get equal speed. Mildly preheating the joint accomplishes this same purpose.

When using a soldering copper, the tool can be tinned with this alloy by using zinc chloride rather than a salammoniac block. The authors

(Continued on page 96)

While the Soldering Iron Is Much Used, Even in Mass Production, Many Other Means of Heating the Joint Are Available. (General Electric photo.)

Sackcloth and Ashes Department

With humiliation we correct an error of a type that should never appear in a technical publication. At top of second column, page 1061 of the December 1942 issue, in the table showing composition of available "addition agents", the content of vanadium and zirconium was interchanged for the last three alloys. It should read (and I hope this is right):

Element	A	B	C	D	E	F	G
Aluminum	7%	—	15%	13%	6%	10%	12%
Boron	0.5	11	1.5	0.5	0.5	0.2	0.2
Calcium	10	—	—	—	—	—	—
Manganese	—	—	20	8	—	—	—
Silicon	35	3	25	—	35	—	—
Titanium	10	—	15	20	10	15	20
Vanadium	—	—	—	—	10	25	13
Zirconium	4	—	—	4	6	—	—

CRITICAL POINTS

BY THE EDITOR

Followed a recommendation to visit a certain firm on the home front (name deleted by agreement) for its experience should encourage others who now fear trouble in changing from tried and true steels to new NE analyses.... This firm manufactures a type of rugged construction equipment wherein service is unusually severe. One substitution is made in an irregular 3-in. tube with ⅜-in. walls, threaded internally at one end and splined internally at the other. Such a design is inherently full of mechanical stress-raisers and many fatigue failures had occurred through the threads by tension impact. The part had been made for years of "Krupp analysis" (S.A.E. 3310, 3½% Ni, 1½% Cr), pack carburized at 1625 for 36 hr., oil quenched *inside and out* from 1450° F. in a spray fixture, and drawn at 400°. Surface hardness was C-60, core hardness C-35. This treatment, as anticipated by theory and demonstrated by experiment, puts about 100,000 psi. compressive stress (residual internal stress) in the dangerous threaded section, and therefore should give that much added insurance against failure from tension loads. Despite this residual stress, and a carefully cut, round-bottomed thread, service failures were discouragingly high.... The chief metallurgist early studied the possibilities of "hot quenching", gaging its effect by tests on an old-fashioned alternating impact machine (wherein a grooved rod is hit by a falling hammer alternately at two points 180° opposite each other). Test pieces made with the old heat treatment would fail by fatigue in this test after 20,000 impacts; when the carburized piece was quenched from 1450° F. in *hot* salt at 300° F. and held 2 hr., then air cooled the rest of the way and drawn at 400° F., it would stand 70,000 impacts. Better than this, when the *part* was hot quenched in this manner in production, service failures dropped 85%!

"Krupp" Steel Improved by Hot Quenching

....Fortified by this correlation between alternate impact test and actual service of this critical machine part, this progressive firm approached the problem of substituting a steel considerably lower in nickel and chromium than the old Krupp analysis with a good deal of confidence. This new steel contained 2¼% nickel, 1% chromium and 0.35% molybdenum. Equivalent or better alternate impact tests were achieved with it after hot quenching, except that the stay in the bath (salt at 300° F.) was increased to 8 hr. and the subsequent draw omitted. (Drawing is supposed to relieve internal stress and so improve impact resistance, but in the particular machine parts they are better left in than taken out because the high internal stresses near the surface are in compression and the surface works in tension.).... Pity now the struggling metallurgist! The new steel is only getting into production when he is notified indirectly from Washington that, while it is using less nickel and chromium than the old Krupp analysis, it is consuming too much molybdenum, and can he please use NE8620, containing 0.5% each of nickel and chromium and 0.20% molybdenum, four sample bars of which are coming by express. So the testing machine gets going again, but although it is no trick to carburize NE8620 to C-60 on surface

and C-30 in the core, the test pieces fail down around 20,000 impacts or less, a figure that would indicate a return of service failures to the large number of parts returned in the old days. After trying many variations in the heat treating cycle, the metallurgist turned as a last resort to the carbide concentration at the surface, reasoning that its presence hardly helped the tensile toughness, and its absence might. Undesirable excess carbides from pack hardening could be diffused by subsequent annealing, but it was thought easier to carburize the pieces in natural gas for 3 hr. at 1700° F., giving a relatively shallow eutectoid case. When such pieces are quenched from the high temperature of 1500° into 300° salt and held 8 hr., cooled and used without a draw, they withstand 80,000 alternate impacts (better than the best of the old Krupp parts) and in all probability will fill the service requirements.

"Krupp" Steel Equalled by NE Steel 8620

ON TO KANSAS CITY in another of those 60-mile-an-hour, smooth riding, diesel-engined trains the western railroads run — greatly to their profit, to judge from capacity loadings — and marveled much at the way Fred Harvey feeds the multitudes. (Eastern railroads please notice that it is not *necessary* to throw unpalatable food at diners, even in wartime.) ....And so out to Sheffield Steel Corp., Armco subsidiary that is an outstanding example of the American steel industry's ability to make good steel out of available raw material, no matter how forbidding. For here, in the middle of the Great Plains, are five 100-ton openhearths running on nothing but light country scrap, and I mean scrap. As explained by F. A. McCoy, chief metallurgist, the refining practices are about the same as used on the West Coast since the last war. Heroic measures are required to get the voluminous raw material into the furnaces without serious delays. Traffic congestion is avoided by handling one-third the charge under a second craneway. Here have been built two large cupolas, alternately in blast and being repaired, charged by skips like a blast furnace, and tapping continuously into a 200-ton mixer. The molten metal naturally has picked up about 3% carbon from the coke, but this is a necessary addition to an openhearth making medium or even high carbon steel — but it also picks up sulphur. This surplus sulphur is removed by alkali treatment as follows: When an openhearth furnace is ready for a "drink" of hot metal, 40 lb. of soda ash is dumped into a preheated ladle and 30 tons of molten iron drawn from the mixer. Reaction is rapid; the ladle is moved aside, the caustic slag skimmed off by wooden hoes, and the iron (now cut from 0.15 down to 0.07% sulphur) immediately poured into the waiting openhearth. Since phosphorus is not a problem the openhearth slags can be worked to remove sulphur, and the resulting steel carries ordinarily 0.05% sulphur (or 0.04% if specifications require)....Much steel is bottom cast in 1-ton ingots; 30 are grouped around a single gate, so a 110-ton heat can be cast from four spots. While Sheffield's normal output is wire, rod, reinforcing, bolts, spikes, bars and light structurals, its quality is attested by the ability to turn out plow steel wire for hoisting cable. Now it is also making shell steel rounds for medium caliber artillery.

Steel From 100% Scrap

TOLD by Don Norquist, laboratory metallurgist at Sheffield Steel, how they make constant use of calculated hardenability of S.A.E. 4150 heats for armor piercing shot, using ladle analyses and Grossmann's diagrams (see last July's data sheet in *Metal Progress*). Heats figuring on the low side of the hardenability range are scheduled for rolling into bars for 57-mm. shot; those on the high side are rolled into bars for 75-mm. shot. The exact hardenability is later determined by a Jominy end-quench test on the rolled bar. Norquist says that cast test pieces give erratic hardenability tests, but now and then when the Jominy test on the rolled bar was out of line with the calculated hardenability, the test piece itself was analyzed and found to be at variance with the ladle analysis. Hardness 1½ in. from the end of an end-quench test piece of 4150 may vary from C-40 to C-60 and the heat still be within chemical limits, so the importance of such testing to the man who handles the hardening treatment is apparent. Hardness of C-50 at 1½ in. on the Jominy bar corresponds roughly to a Grossmann hardenability of 4½ in. (round that will just harden to its center in an ideal quench), while C-55 at 1½ in. on a Jominy bar corresponds to ideal hardenability of 5 in. Knowing this it is easy to direct a certain steel into the plant which has the proper hardening routine.

Calculated Hardenability Guides Mill Schedules

In the December 1942 issue, the desirability of embarking on a program to produce sponge iron was argued pro and con. The aim of such a program would be to produce melting stock for steel furnaces. It should be remembered that another class of material, somewhat allied, has entirely different uses in the field of powder metallurgy. Numerous iron powders of this sort have been commercially available for many years, and the following article gives a general description of them, their properties, and their uses.

IRON POWDER

BY CHARLES HARDY
President Hardy Metallurgical Co., New York City

PRIOR to the outbreak of the present war in Europe, the use of iron powder was very limited. This country relied almost entirely upon imports for its supply. A minor production of iron powder was carried on in the United States and this production will be referred to below.

The bulk of iron powder used in powder metallurgy for bushings and bearings was imported from Sweden, but the entire quantity amounted to but a few hundred tons. However, during the last ten years considerable efforts have been made to produce suitable iron powders for other purposes besides the manufacture of bushings and bearings, and again Europe supplied the quantities of iron powder that were then actually produced and available for import.

In the meantime, however, research work was carried on in this country in an effort to produce iron powder by various methods and from various raw materials, such as by the reduction of magnetic ore or mill scale, and from scrap — mainly borings and filings.

In order to determine as far as possible the merits of the various iron powders available, the Hardy Metallurgical Co. developed a standard test procedure which has been applied to most of the available irons. Testing was carried out as follows: The iron samples as received — whether of Swedish, German or French origin, or those produced in the United States from mill scale or from cleaned and reduced magnetite — were compressed into short square bars. These compacts were then sintered for two hours in hydrogen and subjected to a bending test, to cold forging until edges cracked, to hot forging, and to a test for tensile strength and elongation.

As this is a general rather than a technical article, presentation of all details of these tests is out of place. The accompanying illustration, however, well illustrates the results. As the same treatment was given to all irons received, no matter what their origin or method of production, a very full and comparative record has been collected.

It is probably well to state here that the all-inclusive term "iron powder", without any additional explanation, does not convey to the user what chemical and physical characteristics he may expect to receive. For example there was submitted to one of the most famous laboratories of the United States a sample, which analysis showed to be 99.87% metallic iron and the remaining 0.13% mainly oxygen, yet the laboratory informed the writer that he had been supplied not an iron powder but an "alloy". Not the chemical, but the spectrographic analysis showed the presence of copper!

For convenience the various iron powders have been classified under five headings, according to the method of production and the application, each group having its own application depending upon its specific characteristics:

Group I — Our first work with iron powder dates back 15 or 20 years when it was necessary to supply a very pure, high grade iron powder, particularly with the lowest percentage of phosphorus and manganese. To produce this iron

powder we used bar ends and sheet cuttings of the finest Swedish iron. Though this iron would be termed "scrap", and scrap was available at about $20 per ton, more than three times that price was paid for the raw material. It was dissolved in sulphuric acid and the resulting hydrogen collected and purified. The resulting iron sulphate crystals were roasted to eliminate the sulphur, and the iron oxide subsequently reduced with the purified hydrogen. The result was a very pure iron suitable for use in making batteries, telephone cores, and other electrical equipment. The iron so produced is very finely divided; the most of the particles are probably finer than 325 mesh.

Iron of this nature is still produced on a large scale in this country, and since the Swedish raw material is no longer available on account of the war, a domestic high purity iron has been found to take its place. On account of its very fine grain size this iron powder does not lend itself to the common run of powder metallurgical purposes, and it has a very high compression ratio. It is very expensive and unsuitable for the manufacture of cores or bushings, but it is still an ideal material for special purposes and has already found application in the fields of radio and electronics.

Group II — Carbonyl iron is a product which until recently was imported from Europe. It is produced from the decomposition of iron carbonyl gas. Its grain is globular in shape, and it has probably the smallest uniform grain size. Like the iron in Group I, this iron has an appreciable application, but again it is an iron which does not lend itself to the every-day uses of powder metallurgy. However, even at its present high price it commands a good market particularly in connection with the war effort. Neither Group I nor II, although of great importance, can be classified as "big tonnage" iron powders.

Group III — This is the Swedish iron which was imported under the name of sponge iron. Sponge iron is produced from the fines resulting from mining iron ores, and is reduced by either charcoal or anthracite. Neither process has produced an iron powder with a *high* percentage of metallic iron. The analyzed total iron content is high, but as long as some of the iron is present in the form of iron oxide, this iron oxide should really be classified with the impurities. The use of charcoal for a reduction agent generally leaves a higher oxide content and anthracite a lower, but anthracite introduces impurities contained in the coal, such as sulphur. Swedish production, starting with a by-product ore, is cheap, allowing the iron to be marketed here at a price of from 7 to 10¢ per lb., depending on the mesh size of the particles and freedom from silica, alumina, and other substances. Much of the remaining oxide is reduced by the hydrogen or carbon monoxide atmosphere in the sintering of the compacts,

Photograph of Test Pieces for Five Varieties of Iron Powders. Tensile tests on the French iron gave 38,000 psi. ultimate and 30% elongation

which creates, of course, a certain amount of porosity — not a fault when the article is a "porous" bearing, but a matter of great moment when dense parts are to be produced.

Iron From Reduced Oxide

Group IV — Prior to the outbreak of the war there were many years of efforts in this country to produce sponge iron and perhaps subsequently iron powder, which efforts have been described in a number of pamphlets issued by the U. S. Bureau of Mines, and summarized in last month's *Metal Progress*. The outbreak of the war in 1939 eliminated all possibility of imports from Europe, and since then, efforts here have been multiplied. Group IV deals with the gaseous reduction of iron from mill scale, magnetite ores and oxidized fines from iron grindings and filings. While encouraging products were obtained from ores, their commercialization has not progressed very far as yet due to the fact that, while some of the mines are able to concentrate their iron ores to 68 to 71% iron, it has been impossible to eliminate the alumina, magnesia and silica of the gangue. Presence of these impurities and the incomplete reduction of the iron oxides have been the reasons why there has been no large scale production of iron powder from the ore.

There is an appreciable tonnage of iron produced in this country from mill scale by either carbonaceous gas or hydrogen reduction. The resulting iron finds a market in a great many applications where great physical strength and purity of the iron is not the main requirement of the consumer. If, however, the specifications for the iron are rigid, this iron will not meet them. The mill scale that forms the basis for manufacture is obtained from the steel rolling mills which cannot guarantee a uniform quality because the analyses of the steels vary from day to day, and a certain amount of chromium or nickel or other alloy finds its way into the scale. These mills do not have the facilities, nor during the war any possibility, of separating scale from the different grades of steel. Hence the iron varies from batch to batch and cannot be guaranteed to meet definite chemical specifications. However, it is fairly cheap and finds a number of outlets, particularly where copper and other powders are added to the iron powder.

Group V — Electrolytic iron powder. When it was found that copper powder, made by electrolysis, was of high purity, and the process permitted a variety of controls over grain size, grain structure and apparent density, those engaged in its manufacture in Europe and America started to produce iron powder by electrolysis. From the very beginning this iron powder showed a superiority in quality through the entire absence of gangue and a very low carbon content. As a matter of fact electrolytic iron rarely exceeds 0.002% carbon, which made the iron more ductile and amenable to compression. Tests for tensile strength, elongation, forging and bending are of a different and higher order than those for powders produced by other methods. (Of course iron powders produced by electrolysis are annealed before use.) A great many tests have been performed on electrolytic iron powder for alloying purposes, and where — as in the alnico magnet — the physical and chemical requirements are of the highest, this powder has met all of them. Alloys made with nickel and chromium powder have shown physicals not obtained from iron powders made by other methods. Hardness up to Rockwell C-60 was obtained in the case hardening of parts made from electrolytic iron powder.

Cost of Commercial Powders

During the panel discussion on powder metallurgy at the last Metal Congress in Cleveland, October 1942, the question of price played an active part. Opinion was divided. Some laid particular stress upon the need for cheap iron powder at a price, let us say, of 5¢ per lb. Others were more interested in quality. The latter group was divided into *(a)* those who would, through quality, save material and expensive machining, and *(b)* those who must have quality for the particular application, whatever the cost of the material.

Amongst the users in class *(b)* above are the manufacturers of cores for telephone, radio, television and other parts where magnetic permeability is of prime importance.

It will, therefore, be seen that iron powder should not be judged merely by the name "iron powder", but by the application for which it is needed.

As far as price is concerned, it would seem that reasonable wishes can be met. Lately a powder, called "iron powder", has been offered with a mesh size of 200 or less at a

(Continued on page 126)

LETTERS FROM HOME AND ABROAD

Transformation of Highly Alloyed Austenite

THE SECOND PARAGRAPH on page 896 of the November issue starts thus: "A spirited discussion arose between adherents of this paper [Payson and Klein's] which reported about 20% austenite retained at room temperature, and those of Gordon, Cohen and Rose, who reported about 2% retained." It was vice versa, as pointed out by several correspondents.

Quick Immersion Technique for Molten Steel Temperatures

Sheffield, England

To the Readers of *Metal Progress*:

Investigations in Britain during the last few years on temperature control in steel melting furnaces have centered 'round the development of a satisfactory "quick immersion technique" for measuring the temperature of molten steel by a platinum thermocouple. A description of a suitable instrument for this purpose was given just before the outbreak of war in the Eighth Report to the Iron & Steel Institute on the Heterogeneity of Steel Ingots.

An essential feature of this instrument is the fact that the hot junction of the thermocouple is protected only by a thin silica sheath which allows the thermocouple to attain the bath temperature in a few seconds; hence the instrument need be in the furnace for no longer than 10 to 15 sec. to obtain an accurate reading. This silica sheath is generally renewed after each immersion.

Since that report was issued, investigations in a number of Sheffield steel works with instruments of this pattern have led to some modifications in the details of their construction, but to no essential change in design. One interesting modification has been a carbon block to protect that part of the thermocouple immediately above the thin silica sheath which is partly immersed in molten slag during the time a temperature reading is being taken.

Previously, insulating blocks of diatomaceous materials have been fitted in this position (as well as in the remainder of the length of the thermocouple) and have served satisfactorily for a reasonable number of readings, but the carbon block (turned from waste electrode material) has the property of not being wetted by either acid or basic slags, with the result that it appears to be practically unaffected even after numerous immersions in the molten slag.

If such instruments are to be used for the control of steel making operations, it is obviously important that the extent to which temperature may vary from point to point in a molten steel bath should be known, because this will determine to what extent a single temperature reading may furnish a reasonably accurate picture of the condition of the metal bath as a whole. It may be expected that temperature will be fairly uniform in a high frequency furnace, in which regular circulation of the metal is produced by the heating current, or in an openhearth furnace during and immediately after the boil, but a quiescent bath heated from above is likely to show temperature differences between the upper and lower layers of the molten metal. In such a case, is it possible to obtain a useful indication of bath conditions by a single temperature reading and, if so, at what position and depth in the bath?

Variation in metal temperature in a variety of steel making furnaces has recently been examined by D. A. Oliver and T. Land, who, in a paper entitled "The Temperature Distribution in the Liquid Steel in Various Steel Making Furnaces" presented at the May 1942 meeting of the British Iron & Steel Institute, give the results of numerous temperature measurements in 25 and 40-ton acid openhearth furnaces, 30-cwt., 3-ton, and 12-ton basic electric arc furnaces, and a 100-lb. high frequency furnace.

Their results indicate, as might be expected, that very small differences exist in any of the furnaces when the molten metal is on the boil, but larger variations — up to an observed maximum of 80° F. — are built up during the finishing stages when the metal is quiescent. Rabbling reduces these differences and is recommended prior to taking an immersion reading.

The authors conclude that, providing a suitable position is chosen for the temperature measurement, the observed single reading is likely under normal conditions to be representative of the mean temperature within ± 20° F., though under poorer conditions this limit may be doubled.

J. H. G. Monypenny
Chief Metallurgist
Brown, Bayley's Steel Works, Ltd.

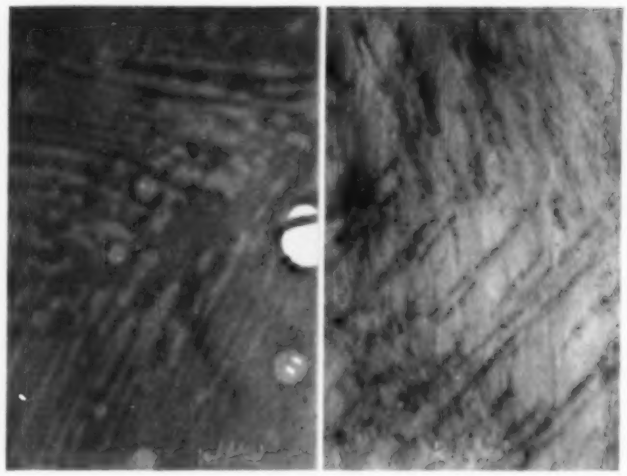
Metallography by Electron Microscope

Schenectady, N. Y.

To the Readers of *Metal Progress*:

The use of the electron microscope in metallography has developed rapidly in the last few months, and we thought it might be interesting to learn of some of this work.

A beam of electrons acts very much like a beam of ordinary light in many ways, except that it has about one fifty-thousandth the usual wave length. Light cannot be used to make detailed images of objects much smaller than its wave length — about half a micron — but the wave lengths of ordinary electron beams are so small that they can be used to make detailed images of objects as small as atoms, at least in theory. Although the contemporary electron microscopes are very far from perfection, they already can give images of objects as small as 0.001 μ, an improvement of 500-fold over the best light microscopes. (Note the clarity and definition in the accompanying example of structure of beryllium copper.) The useful magnification of an electron image is, therefore, about 500 times greater than that of a light image, under the most favorable circumstances. In the electron microscope we obviously have a tool for examining the fine structure of specimens to a degree of intimacy never before possible, and that is why such effort has been put into metallographic studies with this instrument.



Left: Electron Micrograph of Martensite, Showing Part of a Feather. Right: Slightly aged beryllium copper, showing precipitate. Magnification is moderate, as indicated by the length of one micron on the margin; it is about 4500 diameters

Most electron microscopes in use now produce magnified images only of very thin specimens — 0.1 μ or less — by using transmitted electrons. Ordinary metallographic specimens are much too thick to transmit any electrons and, therefore, cannot be observed directly in these instruments. However, by making a thin mold of the etched surface of a thick object and then examining the mold in the electron microscope, the surface contours of the object can be observed. Several ways of making these molds, or "replicas", of the surfaces of metallographic specimens have been devised; we shall describe only the one used in our laboratory.

The specimen is polished and etched in the usual way to give a good image at 1000 diameters under an optical lens system. It is then carefully dried, dipped into a dilute solution of a plastic (such as polyvinyl formal), drained, and the solvent allowed to evaporate. This process leaves the metal coated with a thin film of plastic, flat on the outer surface, but following the most intimate details of the metal's surface with its under side. The thickness of this plastic film depends on the concentration of the solution and can be varied to suit the sample;

ordinarily a film 0.05 μ thick gives good results.

The plastic film is then peeled from the sample under water and brought to the surface, where it floats, spread out by surface tension. This film then can be picked off the water surface and examined in the electron microscope. Where there was a high spot on the specimen, the film is thin and more electrons get through to reach the image of this region than reach the images of thicker parts of the film, where the specimen's surface is lower. Thus, the image shows high points of the sample bright, and low points dark, just as does an ordinary light microscope. Starting with a polished and etched specimen, the time necessary to produce an image in the electron microscope need not be more than 5 min.

Among the most immediately interesting kinds of metallographic specimen are those in which precipitates too fine to resolve with the light microscope are suspected. The suspected precipitates have been discovered in several cases. The very fine cementite plates in a martensite feather, which are shown in one of the adjoining reproductions, form an example. Another is the plate-like precipitate in beryllium-copper, shown in the right hand view.

It is hoped that many more examples of this interesting kind will appear as our work continues. In this way it may be possible to learn more about the fundamentals of precipitation hardening. Such knowledge should lead to new materials with superior properties.

David Harker *and* Vincent J. Schaefer
Research Laboratory
General Electric Co.

Use of Replica Coatings in Metallography

Philadelphia, Pa.

To the Readers of *Metal Progress*:

Much interest is now centered around the latest phase of photomicrography and its use with the electron microscope. To metallurgists this new scientific tool in its beginnings carried little promise until some technique was worked out for its use with metallurgical specimens. It would seem that definite advances have been due primarily to the means for producing thin transparent replicas of the metal surfaces. An excellent description of this use is found in *Transactions* ⊕, Dec. 1941, p. 837, in the article on "Formation of Pearlite", by Robert F. Mehl.

That there is nothing new under the sun is a worn but truthful adage. It is strange there is no mention made by any of the researchers of the work done by L. V. Foster (a member of the Scientific Bureau of the Bausch & Lomb Optical Co.) He published a paper as far back as 1923, on "Transparent Metallography" through the use of replica specimens from metal surfaces. This was read at the 5th annual convention of the American Society for Steel Treating at Pittsburgh, and was published in the *Transactions* for April 1924, p. 413.

J. I. Wexlin
Captain, Ordnance Dept., U.S.A.

Editor's Note: Doubtless the reason Foster's work was forgotten was that his method showed no more under an ordinary microscope than could be seen more simply by reflected light. The replica method is not at all new; one of the oldest and most important of its applications is in making cheap reproductions of ruled gratings for spectroscopes. It would be difficult (and probably fruitless) to find the real inventor's name.

Magnetic Balance for Inspection

Cambridge, Mass.

To the Readers of *Metal Progress*:

I wish to emphasize the wide applicability of the magnetic sorting method described by P. E. Cavanagh in his letter in September *Metal Progress*. The method may be used for sorting or inspection, and will discriminate between deep and shallow-hardening steel, indicate both hardness and depth of case in carburized parts, and give evidence on both quench and draw temperature.

A pair of balanced coils and a cathode-ray oscillograph constitute all the essential elements. Some degree of control of the balance may also be added. This system would appear eminently suitable for repetition inspection of such parts as armor piercing shot, the only difficulty being that involved in setting up acceptance and rejection limits on the basis of an adequate number of calibration tests.

The method, using the closed loop on a cathode-ray tube mentioned by Mr. Cavanagh, was published in the *Proceedings* of the A.S.T.M. for 1927 as an Appendix to Report of Committee A-8 entitled, "A Method of Graphic Representation of Magnetic Characteristics". More applications should be made of this inspection system.

A. V. de Forest
Professor of Mechanical Engineering
Massachusetts Institute of Technology

"Case Depth"

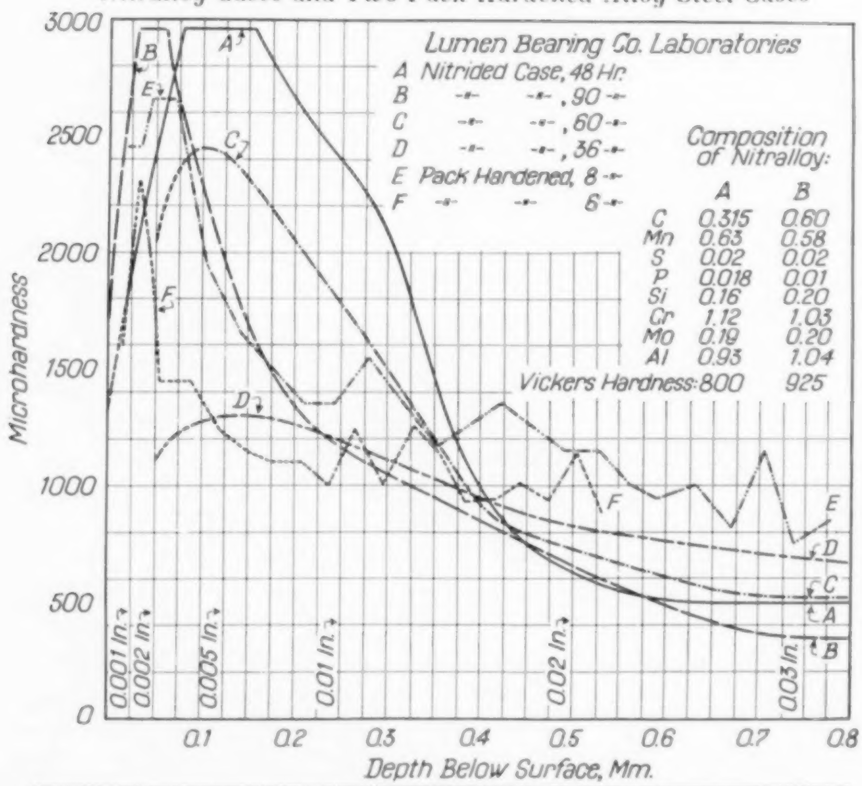
Buffalo, N. Y.

To the Readers of *Metal Progress*:

The Editor's "dumb question" on p. 233 of the August '42 issue ("What is the meaning of the term 'case depth' and how do you measure it?") might be sufficiently answered by the article "Case Depth Measurement" in Metals Handbook, page 768, except that the commercial measurements are still unstandardized.

The attached diagram shows the microhardness as determined by the microcharacter of six cases. They are not exceptional ones but represent "good practice". Curve *F* is particularly interesting because it is of a carburized automotive worm gear like many thousands put out by a firm of national reputation. In routine tests of these gears Brinell tests were made on flat surfaces and the width of the darkened etched rim on a metallographic surface was accepted as the depth of case. The darkened rim was found to be not less than 1/8 in. in width and this officially constituted the "depth of case"; 1/8 in. represents 3 mm., and the horizontal scale of this diagram goes about one quarter that far. It is seen that the really hard layer of the worm was on the order of 0.001 rather than 1/8 in.

Microhardness (by Microcharacter) of Four Nitrided Nitralloy Cases and Two Pack Hardened Alloy Steel Cases



Our studies were taken of gears as heat treated. In order to reduce noise these gears were accurately ground. This meant that 0.002 in. of metal was removed by grinding, and it practically removed the really hard case.

Considering the darkened rim due to etching as representing the depth of case seems to be as yet a common folly.

C. H. Bierbaum
Vice President & Consulting Engineer
Lumen Bearing Co.

Weld Quality Vs. Welding Speed

East Pittsburgh, Pa.

To the Readers of *Metal Progress*:

In the correspondence pages in last August's issue, James F. Lincoln wrote that a very large increase in output per welding operator would result from increasing the size of the electrode. It is not quite so simple as that, as the present writer emphasized when discussing a similar suggestion made by E. W. P. Smith at a recent meeting of the Iron & Steel Engineers.

A large percentage of the welding now being done consists of single-pass fillets. The art has advanced so that the largest electrodes and greatest currents practical are in use in most cases. Further increases in electrode sizes (with their correspondingly higher currents) may cause any one or a combination of the following results:

1. For the same size of weld, an increase in length proportional to the electrode consumption may be obtained but it may be accompanied by an increase in undercutting and porosity and a decrease in the all-important root penetration. Reducing the welding speed will reduce the tendency towards undercutting and poor root penetration but this practice defeats the advantages of using larger electrodes.

2. Larger electrodes require higher currents, and in the majority of cases a generator already operating above rated

capacity must be replaced with one of higher capacity. The result is a higher plant overhead cost and additional orders on already overloaded industries.

3. For a given set of conditions, the use of larger electrodes and higher welding current often results in increased grain size and decreased ductility.

The above points are also true for most grooved welds as well as for fillet welds. It is true that in multiple-pass welds, decreasing the number of passes decreases distortion up to a certain point. Beyond that point the excessive heating of the work itself resulting from increased arc-heats produces another source of distortion. Decreasing the number of passes also tends to decrease grain refinement and ductility.

A. B. White
Research Engineer
Westinghouse Electric & Mfg. Co.

Ghost

Micro by Arthur H. Valentine — Inclusions in Steel Forging

Pistol and Hand Grenade

Plasticity of Cold Metals

Moscow, *U.S.S.R.*

To the Readers of *Metal Progress*:

Plasticity of metals has commonly been measured or estimated from the figures for elongation and reduction of area in the standard tension test. We in the Mechanical Testing Laboratory in the USSR Institute for Aircraft Materials have attempted to set up better and more precise criteria. A first, and simplified, assumption is that the reduction of area is a preferred measure of plasticity for structural and austenitic steels, and for wrought copper alloys, such alloys being those whose microstructure is based on metallic solid solutions.

We have also divided all polycrystalline solid solutions into two fundamental groups depending on the plasticity (toughness, or its converse, brittleness) at low temperatures:

I. Solid solutions based on nickel, copper, silver, aluminum and other face-centered metals which do not become brittle even at very low temperatures.

II. Solid solutions based on iron, magnesium and other metals which, at a definite transition range of temperatures, pass from a tough to a brittle state.

It also appears that the basic metals of Group I are more plastic (as measured by reduction of area) than solid solutions based on them, and this relationship persists at any temperature of testing. This is true despite the fact that commercial high brasses and bronzes have somewhat higher reductions of area than commercial copper. For example:

Commercial copper	70% R.A.
10 to 20% Zn, Al or Sn	80%
30% alloy	70%

However, when these alloys are prepared from materials of maximum purity the generalization holds, for purest deoxidized copper then has a reduction of area of 90%, a 10% alloy of 87%, a 20% alloy of 83% and a 30% alloy of 78%. The anomaly in commercial alloys may be due to deoxidation by the Zn, Al or Sn.

A different picture is obtained from tests of Group II at sub-transition temperatures. For example, iron has a transition temperature (tough to brittle) of about −180° F. Iron-nickel alloys tested at 70° F. have plasticity (R.A. = 65%) that slightly decreases with increasing nickel up to 5% (thus conforming to the action of Group I alloys), but when tested at −325° F. the reduction of area increases from practically zero for pure iron to 40% for a 5% nickel alloy. Similar trends and values are noted for magnesium (transition temperature 440° F.) alloyed with aluminum when tested at 575° F. and at +70° F. In these systems excessively pure alloys do not act differently than the commercial alloys.

The above phenomena have long been utilized for obtaining tough alloys to work at extreme temperatures. The general principles may be extended to discover improved metals, and to guide their fabrication.

Jacob B. Friedmann
USSR Institute for Aircraft Materials

Flakes in NE Steel Billets

Cudahy, *Wis.*

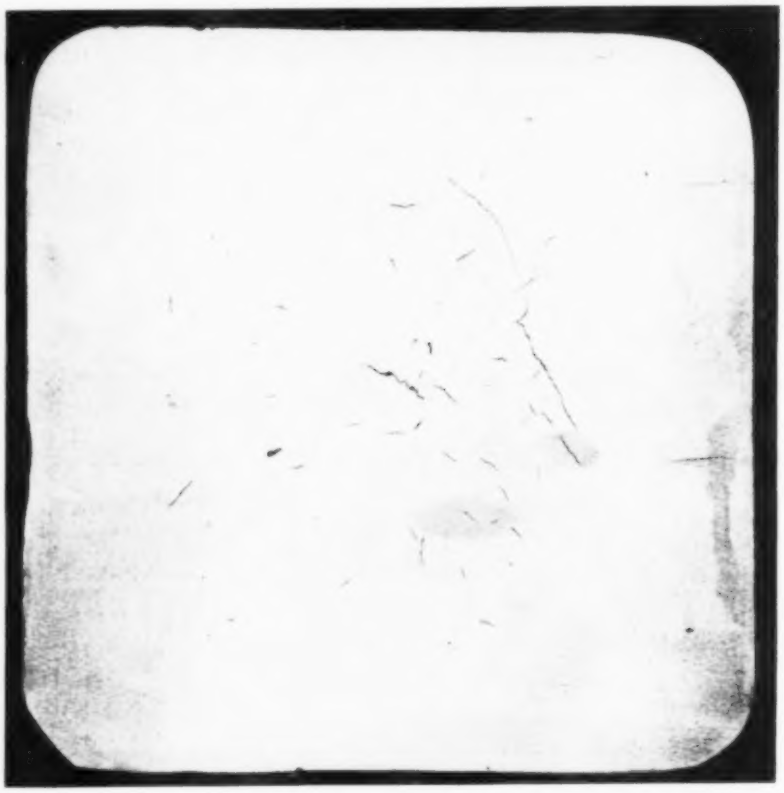
To the Readers of *Metal Progress*:

We wish to call attention to serious difficulties which have attended our first experience with the new NE steel compositions, and which must constantly be guarded against in the manufacture of drop forgings and open die forgings ranging upward from 2 in. in section. We refer to ruptures or bursts known variously as thermal ruptures, flakes or bursts, prone to develop in certain melts of alloy steel which have been rapidly cooled after rolling or forging. (They seldom if ever occur at the surface, and inspection should search out the deeper portions of the metal.)

While the cause of this type of defect is still subject to some disagreement there is apparently no dispute as to the measures necessary for its complete prevention. Three requirements may be mentioned: *(a)* Retardation of cooling should commence at a temperature not substantially lower than 1000° F. *(b)* Necessary rate of cooling will be such that the minimum total interval will range from as little as 92 hr. to as long as 168 hr. in sections we encounter (2 to 12 in.). Total time for complete prevention of ruptures seems to depend upon bar size, temperature at time of burying, rate of cooling, composition, and various more or less obscure characteristics of the metal in various mill heats. *(c)* Retarded cooling must be continued to a temperature considerably lower than many seem to appreciate. It is known that serious ruptures have occurred in blooms and bars withdrawn from the pits at temperatures in the neighborhood of 450° F. Where cooling has been continued to 250° F. no single instance of trouble has been encountered.

Tendency to rupture is distinctly higher in steels carrying nickel and molybdenum together. Compositions known to be particularly hazardous include not only those of high hardenability, such as X4340 (AMS6415), but also and more especially the new NE compositions, such as NE8620 (AMS6274). S.A.E. 4820 has also been particularly bad in bar sizes of from 4 in. upward.

Recent inspection of rolled billets of from 4 to 12-in. cross-section leads to the inference that some steel mills lack full appreciation of the importance of the alloy content even of the low alloy NE steels as a factor in tendency toward flaking. While it is probably true that there is somewhat less danger of flaking after forging a sound bar than there is of flaking as a result of improper steel mill practice, nevertheless, forge shops dealing with the heavier sections involved in many of today's forgings and with compositions and geometry new to them must be cautioned to protect their product adequately *immediately after forging* to prevent serious loss during cooling, especially since the NE steels are now being substituted for such compositions as the 3100, 4100, 5100, and 6100 series, which previously were rolled and forged without extensive precautions to prevent damage by thermal rupture.



Thermal Ruptures in 5-In. Billet of NE8620 as Received From Steel Mill, Sectioned Transversely 10 In. From End. Note absence of ruptures in outer zone. This condition is preventable by proper control of cooling. Slightly reduced in size

Our experience indicates it is necessary to provide slow cooling facilities for all of the NE steels in the 8600, 8700, 8800, and 8900 series in sections much smaller than were given special attention in compositions for which they are being substituted. The maximum section which does not need special cooling precautions is not known by us, either for bars or for forgings, and there does not appear to be any short method to determine these dimensions. Unfortunately successive mill heats of the same chemical composition appear to vary greatly in their inherent susceptibility to flaking. Even in compositions such as X4340 (AMS6415), many heats may be forged into sections as heavy as 8 in. and air cooled from the forging operation without thermal ruptures. To suppose, however, that such practice can be continued without sooner or later encountering tragic results is utter folly.

E. O. Dixon
Chief Metallurgist
Ladish Drop Forge Co.

English Chemical Industry Uses High Carbon 18-8 Ti

Billingham, *Durham, England*

To the Readers of *Metal Progress*:

Various articles in the American technical press have discussed the problem of handling high chromium-nickel (stainless) scrap, and they have been read and discussed with great interest in metallurgical circles in England. Naturally, a similar problem has arisen in this country. The crux of the problem, as stated in the paper by Hubert A. Grove in *Metal Progress*, January 1942, is the maximum carbon content. Any increase in the carbon permissible in the finished steel immediately eases the steelmakers' position and goes a long way towards eliminating the scrap problem — or, at least, postponing its acute recurrence until the defense programs of both countries are going with a swing.

Mr. Grove draws a distinction between material which has to be welded and material which has not. Is such a classification justified? Should not the former category be narrowed by describing it as "material which has to be welded and which has subsequently to serve in conditions of corrosion which will produce disintegration effects"? One can quote cases of extensive use of this material in the welded condition (*e.g.*, in airplane construction) where the service does not involve enough corrosion to cause disintegration or corrosion damage within the expected life of the structure.

Such a restriction of the special category material would, of course, limit the necessity for the precautions which prevent adequate absorption of scrap.

The limitations placed on carbon content when stainless is welded and placed in corrosive conditions arise, of course, from a mass of research and experimental work to which American metallurgists have contributed splendidly. From the user's point of view, the practical result of this work has been to show him clearly the cause of his early troubles and to furnish him with simple tests to avoid trouble with his present-day purchases. Quite correctly, these acceptance tests are severe — they are, in fact, much more severe than many of the subsequent service duties, for, like most acceptance tests, they provide a liberal factor of safety. In the normal days of peace, one used these factors of safety with perfect justification since they could be regarded as normal cover for the known inhomogeneities of most metallic materials. However, stainless, being highly worked from small ingots of carefully made steel, probably contains less "normal" inhomogeneity than most other forms of steel. In fact, records of many hundreds of casts over a period of years have shown few departures in corrosion and disintegration test behavior from that predictable on the basis of composition.

Therefore we have, in this class of steel, a highly dependable material, whose special qualities are regularly reproducible. This degree of confidence has only been built up, of course, as a result of the exacting standards set in the past, but in the present emergency it appears advisable to examine all standards to see if they are not unnecessarily restrictive.

Over a period of years, we in Imperial Chemical Industries, Ltd., have obtained what would appear to be a satisfactory practical answer in purchases of 18-8 class of material. Our supplies, which are very large by standards in this country, are purchased to a specification which permits carbon up to 0.16%. A titanium: carbon ratio of not less than 4½:1 is specified, together with nickel and chromium in the normal quantities for 18-8. Carbon usually is on the order of 0.12 to 0.14%, and every heat is subjected to the copper sulphate-sulphuric acid test devised by W. H. Hatfield. Over a period of years, rejections at the suppliers' works have been negligible.

In service, this material is used for a wide variety of duties in the heavy chemical industry, often under very severe conditions of corrosion. Welding is now done with a columbium 18-8 electrode and no heat treatment of any kind is given to the material after full softening treatment by the producer. Stabilizing treatments of American origin are never used. The performance of this material in, for instance, nitric acid manufacture, has been very satisfactory and our experience for several years has given no indication of necessity for re-imposing more rigorous standards.

Finally, perhaps I might be permitted to add that we, in this country, have been distinctly puzzled by the retention, in America, of plain 18-8 welded and quenched, for severe corrosion duty. With the full knowledge and experience of immunizing elements now available, we have not been able to determine the justification for this difficult and often cumbersome treatment, with consequent demands on valuable high temperature heat treatment plant. We appreciate that certain forms of laboratory test have shown that correctly treated plain 18-8 has superior corrosion, as distinct from disintegration, resistance to certain highly corrosive media. In practice, however, we have not found, even in our severe conditions, that the corrosion resistance of 18-8 Ti is inadequate and, in fact, in a very large plant, we have no record of any wrought fitting having to be replaced in 15 years by corrosion failure.

FRED. H. KEATING
Chief Engineer
Fertilizer & Synthetic Products Branch
Imperial Chemical Industries, Ltd.

MYTHICAL WHITE METAL AND OTHER SUPER-HARD IRONS

WASHINGTON, D. C.

To the Readers of *Metal Progress*:

Legends concerning a mysterious "white metal" capable of imparting extreme hardness to steel and iron still prompt prospectors and inventors to submit many rocks and samples to the Bureau of Mines for tests. This white metal has proved as elusive as the Fountain of Youth sought by Ponce de Leon, yet persons are still persistent in their assertions that there is one.

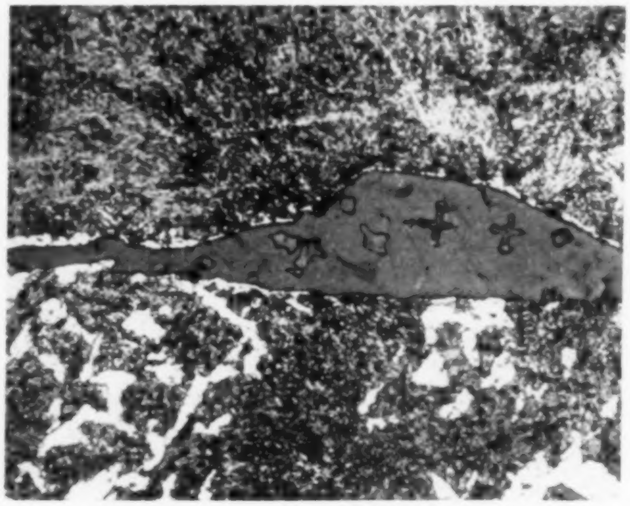
One legend states that pioneers heated the axles of springless wagons while in contact with the "white metal" and that the axles became "glass hard" and would wear two or three times longer than ordinary axles. Another legend recites that wagon tires so treated would "ring like a bell" when suspended and struck with a hammer. There are several versions of these stories, but none apparently is based on fact.

Various laboratories, governmental and commercial, at different times during the past 30 years, have received many kinds of rocks (designated as ores) that are supposed to give remarkable properties to metals, such as making them hard, extremely tough, or resistant to corrosion. The "ores" submitted include altered diabase, olivine, pyroxenite, obsidian, basalt, amphibolite, pyritic quartzite, magnetite, tourmaline, sandstone and, in fact, almost every common rock. Most of the samples come from California and Nevada, but nearly all western states are represented.

Persons who have found what they believe to be ores containing white metals usually test them by placing them in contact with a piece of iron or steel and heating them in a blacksmith's forge.

Tests by the Bureau and other laboratories, following specified procedures, usually have shown that the ores have no outstanding hardening effect, although sometimes casehardening resulted either from heating the metal in contact with carbon, or from the formation of a superficial iron-silicon alloy. Many ordinary fusible rocks, and even fluxes without rock, will give the same results. The Editor has already pointed out, in "Critical Points" for Dec. 1941, how a fire assay of any iron ore reduced with carbon

Ghost



Micro by Alex. Gobus — Complex Inclusion in Defective Steel

Has This Steel Been Double-Crossed?

under a borax flux, will produce a cast iron button containing enough carbon and boron to be white and hence exceedingly hard.

The frequent claim of "glass hardness" probably is due to the fact that slag adheres to a piece of iron or steel and is mistaken for hardened metal.

Various rocks whose virtues were presumed to be due to their content of platinum, vanadium, uranium or other rare metal had only the slightest traces of these metals or did not contain them at all. They were simply good fluxes and, as such, cleaned iron but had no power to alter its properties.

It must be concluded, therefore, that the various unsubstantial claims that have been made were due to careless tests or to erroneous interpretations of tests. Although under certain favorable conditions it is possible to effect a hardening or alloying action or to extract metallic iron from some rocks, the difficulty of obtaining reproducible results and of controlling the composition of the alloy would make the practicability of such procedures doubtful.

C. W. Davis
Chief Engineer, Metallurgical Division
U. S. Bureau of Mines

Fixing Bearings in Steel Shells Without Using Tin

Charleston, W. Va.

To the Readers of *Metal Progress*:

Since the saving of tin in bearing metals is a matter of national importance, and since the method for fixing bearings in steel shells described in last August's *Metal Progress* uses considerable tin (even though less than in conventional practice), we wish to make the following contribution from our experience:

Lead-base alloys do not adhere satisfactorily to a shell tinned with pure tin or a high tin alloy. Low melting point compounds of lead and tin may be formed at the interface, resulting in a poor bond under service conditions. Also, since tin is a restricted, strategic material, it would be better to eliminate it entirely from the tinning operation.

We are at present running tests on substitute lead-base bearing alloys, and have found that the tinning can be done readily with a 95% lead, 5% silver alloy to which the lead-base bearing material will adhere perfectly.

We agree that cleaning of the shells is extremely important, but also know from experience that most of the difficulty arises from poor bonding between the bearing alloy and the tinning.

Shells of either steel or bronze can be tinned by hand with the lead-silver alloy. Our present procedure is as follows:

1. Heat the cleaned shell uniformly by any approved method — preferably from the back with a large torch, keeping the flame away from the clean face.

2. Brush the surface thoroughly with zinc chloride-ammonium chloride flux.

3. Rub the surface with a stick of lead-silver alloy until a small amount is melted off.

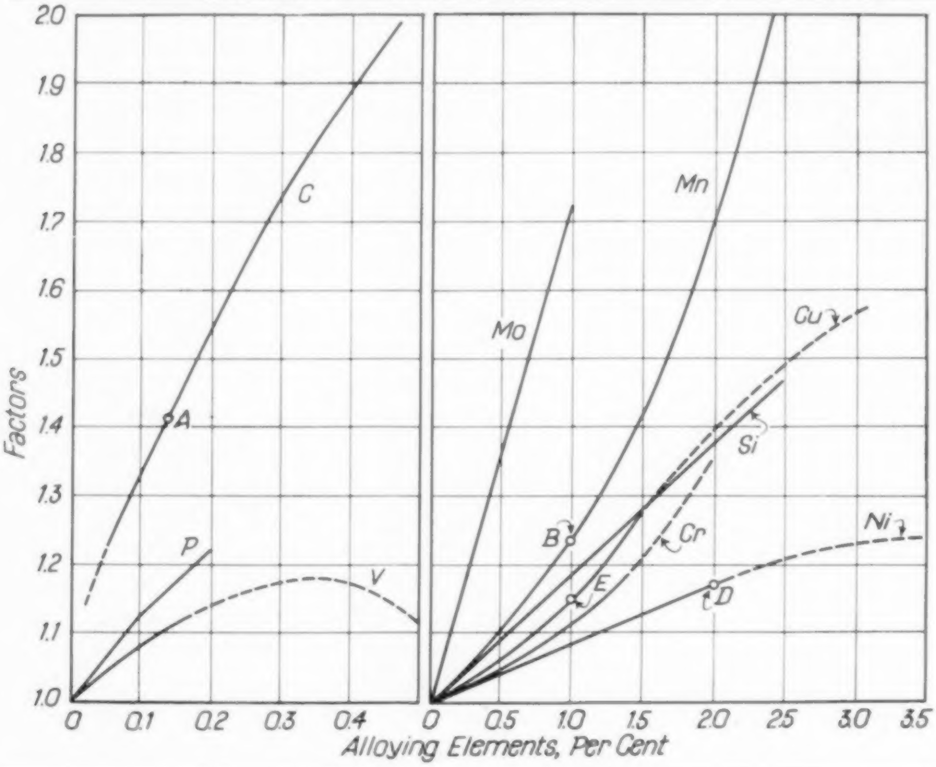
4. Dip a clean wire brush in flux and rub the molten metal vigorously over the immediate surface. Use more tinning alloy as needed.

The above flux is made of 11 parts of zinc chloride solution and 1 part of ammonium chloride solution to which sufficient water has been added to bring it to 52° Baumé.

We have used this procedure on all our test lead-base bearings and have always obtained a firm, adherent bond. The elimination of tin is important in view of the present shortage and the cost of the lead-silver alloy is actually less than that of 50-50 tin-lead solder.

Walter Coopey
Engineering Manager
Ammonia Department, Belle Works
E. I. du Pont de Nemours & Co.

This Illustration for R. S. Dean's Statement About Direct Ir 1040, December 1942) Arrived Too Late for Publication. It s firing hood for the experimental kiln at Las Vegas Experiment



Factors Whereby Basic Strength of Iron (36,000 Psi.) May Be Multiplied to Find Ultimate Strength of a Normalized Steel, Knowing Its Chemical Composition (Francis M. Walters, Jr.)

COMPUTING STRENGTH OF NORMALIZED STEEL FROM ITS ANALYSIS

THOSE WHO NEED TO COMPUTE physical properties from chemical composition rather than determine them experimentally can now add a pair of diagrams to their notebooks showing the influence of the common alloying elements on the tensile strength of normalized steel. They have been derived statistically by Francis M. Walters, Jr., of Naval Research Laboratory, and published by the A.I.M.E. in Technical Publication No. 1532. Original data are a large number of laboratory tests on families of steels. Like Grossmann's methods for computing hardenability, the scheme assumes that each alloy in turn affects the basic strength of 36,000 psi. for pure iron by a characteristic factor, scaled from the curves. Take a nickel-copper steel as an example:

Alloy	Content	Factor	Letter on Diagram
C	0.14%	1.41	A
Mn	0.98	1.23	B
Si	0.09	1.02	
P	0.003	....	
Ni	2.03	1.17	D
Cu	1.06	1.16	E

A normalized bar of such a steel should test $36{,}000 \times 1.41 \times 1.23 \times 1.02 \times 1.17 \times 1.16 = 87{,}100$ psi. Actually it tested 85,000.

Antiquarians may consult H. H. Campbell's "Manufacture and Properties of Iron & Steel", first published in 1896, for a formula for the strength of basic steel as follows:

$$41{,}500 + 770\,C + 1000\,P + M + R$$

where C and P are carbon and phosphorus contents in points (units of 0.01%), M is a figure taken from a table for the effect of manganese (which was supposed to vary with carbon content), and R is "a variable to allow for heat treatment". Note that silicon is not supposed to affect the result (and silicon is also missing in a companion formula for acid steel) and in those days seldom or never appeared in the chemical analysis. Computation of two hot-rolled carbon steels noted in the A.I.M.E. publication gives pretty good checks:

No.	Actual	Walters' Formula	Campbell's Formula
1B	55,300 psi.	53,800	52,400
11B	69,100	70,000	70,300

Since the supply of alloying elements available to the steel industry changes rapidly, due to fluctuating imports, variation in demand as ordnance materials are changed, lend-lease exports, and local production and scrap returns, the availability and even the composition of the National Emergency steels are also subject to sudden change. Consequently the alert ASMember, in making the correct applications of these new steels, must rely on fundamental metallurgical principles, as expounded in these papers presented at one of the ⊕ Meetings on War Products.

METALLURGICAL ASPECTS OF THE NATIONAL EMERGENCY STEELS

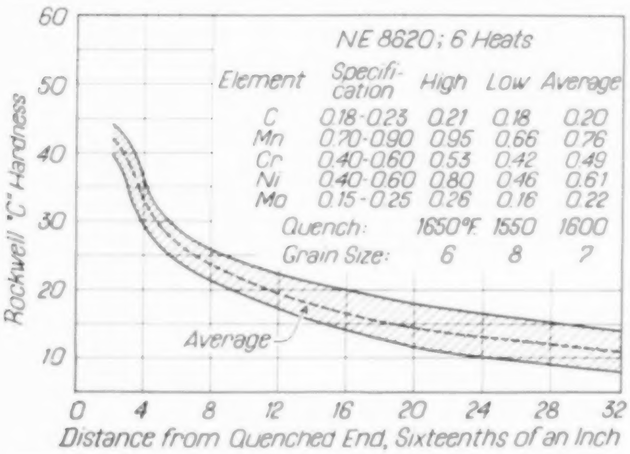
END-QUENCH TEST and ITS APPLICATION

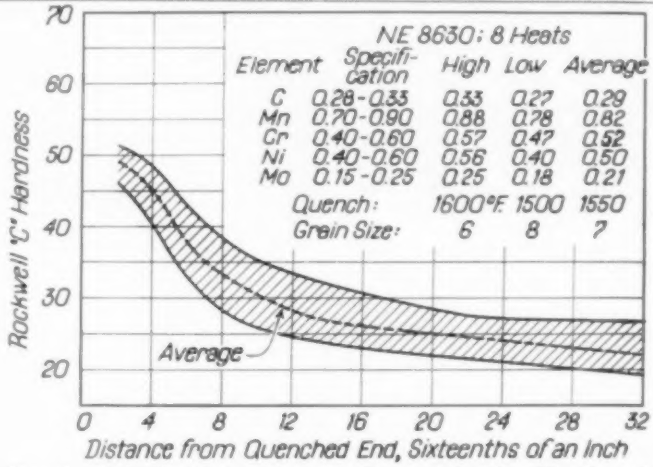
BY WALTER E. JOMINY
Chief Metallurgist, Dodge Chicago Plant
Division of Chrysler Corp.

DURING THE PAST YEAR two societies have adopted a standardized method for making the end-quench test for hardenability. The Society of Automotive Engineers adopted a standard method the early part of the year and the American Society for Testing Materials adopted a tentative method shortly thereafter. The methods agree in their essential parts each to each, and to the method used by the "Steel Standardization Group" and printed in *Metal Progress*, December 1941, page 911. Perhaps the greatest divergence lies in the method of plotting the results; the S.A.E. suggested plotting the results on a modified logarithmic scale whereas the A.S.T.M. agreed to use linear coordinates in a printed form. The method of recording results is, of course, very unimportant except that it is desirable to have a uniform method so that we do not misunderstand one another in examining hardenability curves.

Quite a large number of tests have been made by independent workers at laboratories located in many of the larger plants. These tests have shown that it is possible to get good duplication of results with the standardized methods, test piece and fixture shown in the adjoining sketch. Although it has been found that rather wide variations in the test conditions can be tolerated, it is quite easy to carry out tests as laid down in the standard methods and it would be well for those who are making hardenability tests to read these over carefully so that a standardized method of making the test will be used, and possible errors due to modifications can be avoided. Perhaps the most

Fixture for Hardening Test Piece in End-Quench Test on 1-In. Round Specimen, as Adopted by "Steel Standardization Group"





Bands Showing Variation or Spread in the Hardenability Curves, as Well as Average Results, on Numerous Commercial Heats of NE 8620, 8630 and 8739. Average curve for NE 8630 almost superposes itself on average curve for A 4130, and the former has been approved by the Army

likely error to be made would be to obtain a tight scale on the test piece due to heating in certain atmospheres, and non-uniform cooling would result from the presence of this scale. It is only necessary to keep the scale off the face which will be struck by the water jet and on the sides of the specimen near this surface.

There is one deviation from the standard method that is such a convenience that it is commonly used. This is in the matter of size of test specimen. It will often be impossible to use the 1-in. round specimen, as when a ¾-in. bar size is received, and it may not be convenient to machine a 1½-in. round to 1 in. Although these odd sizes can be used in routine testing and will be quite satisfactory, the resulting hardnesses are not to be compared with 1-in. round standard size specimens. In the range from ⅝ to 1¼ in. hardness variations will not usually be very great. There are exceptions with certain steels and so the precaution just voiced — of carefully noting that any size but 1 in. is not standard — should be followed.

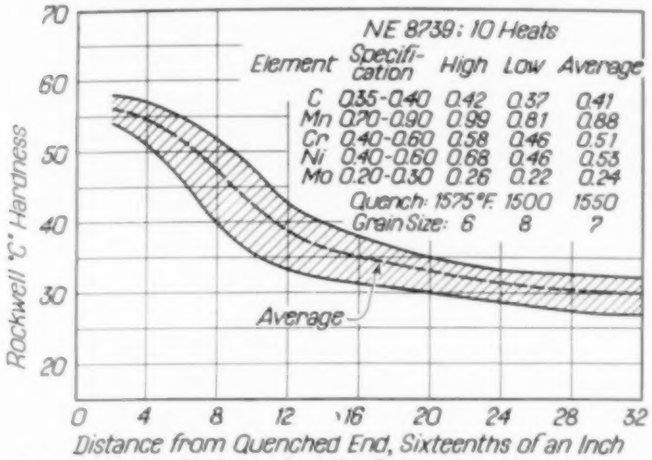
Where for convenience no machining is done on the bars it may be necessary to grind flats deeper than 0.015 in. to get below the decarburized zone when making the hardness survey. No difficulty or appreciable error will result when this is done, even though up to ⅛ in. is removed by grinding, except that the heat generated in grinding may temper the surface if due care is not exercised. (This last remark does not apply, of course, to carburized bars.)

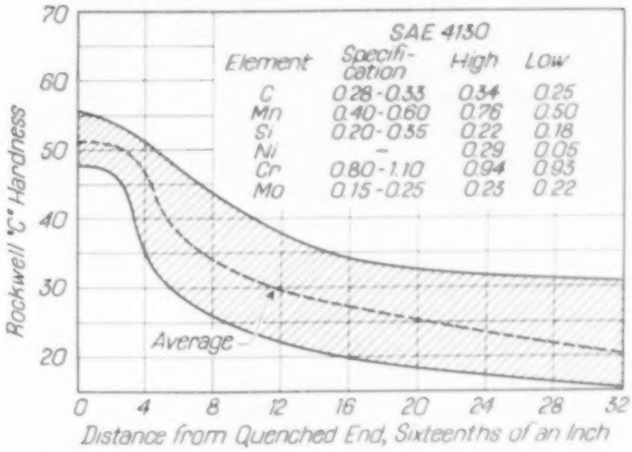
For some reason the test seems to be very seldom used on steel in the carburized condition. If the steel is to be *used* in the carburized condition, I have found it worth while to make the test after carburizing the test piece. Hardenability both of the case and the core can then be obtained by first grinding off 0.015 in. and measuring the hardenability of the case, and then removing all the case by grinding deeper and obtaining the hardenability of the core. Commercial heats which will give trouble from soft spots or insufficient hardness on the carburized surface may be discovered and re-scheduled by this means.

There are two points to consider in interpreting the test which I should like to mention briefly; one is the comparison of steels of various carbon contents, and the other is the interpretation of the meaning of the hardenability test.

Comparing Steels of Various Carbon Contents

In comparing steels of different carbon contents it should be borne in mind that the carbon has a double function. One is to increase the hardenability of the steel and the other function is to increase the hardness of the steel. Its effect on hardenability is relatively small; its effect on hardness is relatively great. When we remember that the measure of hardenability by this end-quench test is the distribution of *hardness* along the sample, the effect of carbon must be carefully considered. A hardness, for instance, of Rockwell C-40 in a 0.90% carbon steel has an entirely different meaning from that same hardness in a 0.12% carbon steel. An entirely different microstructure is indicated in these two cases. This is important for there is a general tendency to increase the carbon as we decrease the alloy in an attempt to find alternate steels. Steels which have approximately the same hardenability curves but differ in carbon content really do not have the same microstructures as quenched or as tempered, nor do they have the same hardenability so they cannot be substituted for each other indiscriminately.





Air Corps as a substitute for the latter for aircraft components (provided the requirements for model tests are satisfied). Note that the width of the "hardenability band" for S.A.E. 4130 as commercially produced is actually wider (the steel is more variable) than for NE 8630

Interpreting the Hardenability Test

With most new tests, attempts are made to read more into the results obtained than is justified. The hardenability test is no exception. We should remember that it will tell only what hardness will tell.

It is true that the end-quench hardenability test was developed for the very purpose of testing new steels to determine whether they can be used as substitutes for steels which are of proven quality. Two examples were given in detail for the selection of gear steels in my article on "Commercial Aspects of Hardenability Tests" in *Metal Progress*, November 1940, page 685. The end-quench test is very satisfactory as a first approximation, in my opinion, because it eliminates the necessity for making up parts and hardening these parts, then determining whether or not the hardness in the parts at the surface, at the center, and through the hardness traverse is satisfactory. A great deal of time and effort is saved in using the test in this manner.

The first step of making a substitution or finding alternate steels is to ascertain the hardenability of the two steels and if their hardenabilities are similar the possibility of a substitution is indicated. However, this is only the *first* step and other tests need to be made to confirm the desirability of the new steel. I have no data nor have I seen any data which would indicate that two steels with the same hardenability will have the same tendency to flake, or the same machinability, or the same resistance to wear, or the same resistance to impact, or even the same resistance to fatigue. It seems to me that they should have the same tendency to distort, although this is far from established. We do know that steels with the same hardness will have the same approximate tensile strength and should therefore have the same resistance to fatigue, but these relationships are very approximate and it is much better not to take too much for granted.

PLANNING HEAT TREATMENT BY S-CURVES

BY R. L. RICKETT
Research Laboratory
United States Steel Corp.

IT WILL BE NECESSARY to assume some familiarity with isothermal transformation diagrams, or "S-curves", and their interpretation. These diagrams are described in a number of papers dealing with the subject which have appeared from 1930 to the present, particularly in the Campbell Memorial Lecture for 1939 delivered by E. S. Davenport, and abstracted in *Metal Progress* in November of that year.

It may be helpful, first, to consider a few general features of these diagrams. The transformation of austenite at constant temperatures below that at which it is stable may be represented on a temperature-time chart by a pair of curves which show the virtual beginning and end of transformation and, if desired, by curves representing any intermediate amount of transformation. To this diagram, information as to the nature of the transformation product may be added. Even if such information is not given on the chart, those familiar with the subject can usually deduce from the transformation behavior the type of structure formed at any particular transformation tempera-

ture, in a steel for which the S-curve is available. The hardness resulting from transformation at various temperatures is usually given on the chart also; these hardness values give a rough idea, at least, of the other mechanical properties to be expected.

To summarize then, the following information may be derived from the isothermal transformation diagram of a steel:

First: The time necessary for a measurable amount of isothermal transformation to begin, and the time necessary for transformation to become substantially complete at any particular constant temperature.

Second: The type of transformation product or products formed at a particular temperature.

Third: The hardness and some idea of the other mechanical properties of the steel after transformation.

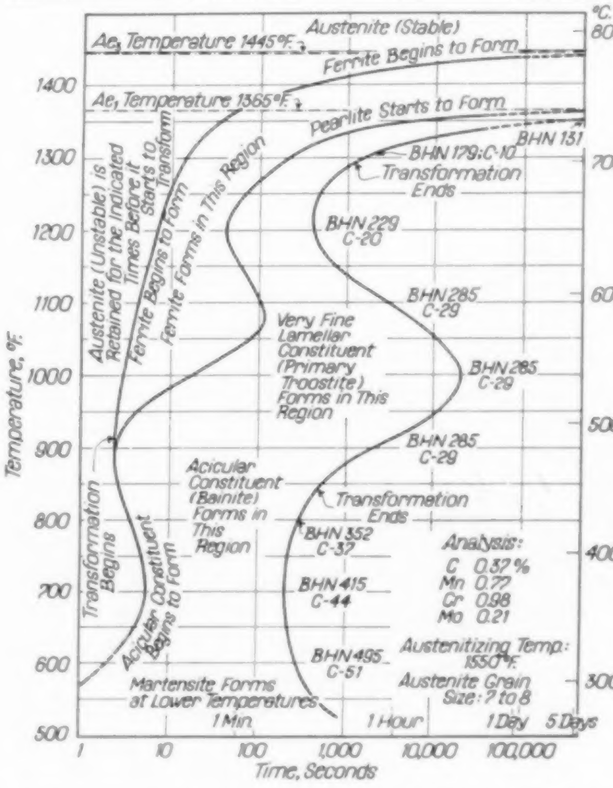
One other point regarding use of the S-curve should be mentioned. As ordinarily determined, these curves portray the course of transformation *at constant temperature* (isothermal transformation). Practical heat treating operations usually, but *not* necessarily, involve continuously changing temperatures, and sometimes this temperature change is extremely rapid. An isothermal transformation diagram may still be used in a qualitative way to interpret what happens under such cooling conditions. If more precise information is required, it is necessary either to determine the transformation diagram for different cooling rates, or to derive such a diagram from the isothermal S-curve. The relationship between the cooling transformation diagram and the isothermal diagram has been discussed in the technical literature, particularly by R. A. Grange and J. M. Kiefer of the U. S. Steel Corp.'s Research Laboratory in *Transactions* ⊕, March 1941, page 85. It will be sufficient for the moment to say that the curves of the cooling transformation diagram lie somewhat below and to the right of the corresponding portions of the isothermal diagram.

A few examples will be cited to show some of the ways in which isothermal transformation diagrams may be useful in connection with heat treating operations. The small diagram used here, by way of illustration, happens to be one for S.A.E. 4140, but for the purpose of this discussion almost any alloy steel diagram could be used equally well. A large diagram for this steel, showing microstructures, has appeared as a data sheet in *Metal Progress*, October 1941, page 517.

First, suppose we want to know the hardenability of the steel. A measure of hardenability is the time before transformation starts at the upper temperature of relatively rapid transformation, or "nose" of the curve — about 900° F. for this steel — since transformation must be avoided on cooling through this range, if full hardening is to be attained. As yet no *quantitative* relationship between this time value (about 2.5 sec. for this particular steel) and depth of hardening has been worked out. However, by comparing the diagram for a new steel with those for steels with which practical heat treating experience has previously been gained, a good idea of the hardenability of the new steel may be obtained. There are, of course, a number of direct empirical methods of measuring hardenability, one of which has just been described by Mr. Jominy.

As another example, we will assume that we do not want to hold the steel in the quenching bath until it is completely cold, but only long enough so that it will harden to some designated depth if subsequently cooled at some slower rate — for instance, in air. Reference to the accompanying illustration shows that if a piece of the S.A.E. 4140 steel to which this particular diagram applies is cooled rapidly in the quenching bath until the selected location is below 800 to 900° F., the piece will harden to this depth even if then removed from the bath and cooled slowly thereafter. Such a procedure may be used to minimize cracking or to enable the part to be straightened while it is still largely austenitic and ductile.

Information derived from S-curves may be

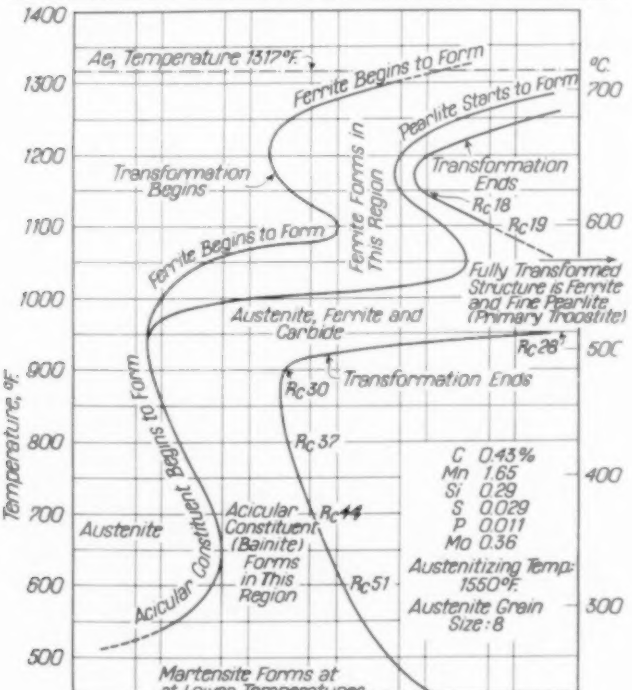


Transformation of Austenite in S.A.E. 4140 (Cr-Mo Steel) at Constant Sub-Critical Temperatures, as Measured in Research Laboratory, U. S. Steel Corp.

applied directly to the heat treatment of steel by the patented isothermal transformation process known as austempering. Information on this process may also be found in the technical literature.

In the foregoing examples we have been interested in hardening the steel. It is equally important to know how to *avoid* hardening when such hardening is not desirable, and in this connection the isothermal transformation diagram may be useful. For example, it will tell us, qualitatively at least, how slowly we must cool to avoid the formation of hard transformation products and to what temperature retarded cooling must be continued. Note particularly the "waist" at 1200° F. in the diagram. If a soft structure is desired, it may be possible to cool fairly rapidly to this temperature, then hold at the temperature of the "waist", or cool slowly through this temperature range until transformation is complete, and then again cool rapidly. Such a cycle, if feasible, is much faster than one in which the charge is cooled very slowly all the way down, as in most annealing operations.

In many instances, microstructure may be as important as hardness; for example, a large amount of ferrite may be objectionable for some machining operations. The diagram shows, even without the photomicrographs, that if a hardness



Isothermal Transformation Curves for Mn-Mo Steel (Similar to NE8442 Except Higher in Manganese) — Research Laboratory, Climax Molybdenum Co.

of C-30 or below is obtained by direct cooling, considerable ferrite will be present, probably as a network. To avoid formation of a ferrite network in such a steel it would be necessary to quench, then temper to the desired hardness.

Many other examples could be mentioned of the way in which information given by the isothermal transformation diagram can be used to obtain the particular type of microstructure desired.

It may be objected that the foregoing examples have been entirely qualitative. This is true, but as one gains experience in the use of such diagrams in connection with a particular heat treating operation, it becomes possible to use them in a fairly quantitative manner. Probably their greatest usefulness, however, comes from the general over-all picture they give of transformation behavior. With this knowledge, many observed phenomena, which otherwise might appear weird and mysterious, can be interpreted on a rational basis. The ability to make such a rational correlation of his observations is not only very comforting to the harassed and perspiring metallurgist, but, more important, it enables him to plan more intelligently the steps he must take to solve his problems or to avoid certain difficulties and pitfalls in the first place.

The general relationships which have been discussed apply regardless of the type of steel, and one who can use isothermal transformation diagrams in connection with the heat treatment of carbon steel, or the S.A.E. alloy steels, can use them equally well in connection with the NE steels. Very few diagrams for the latter are available as yet; the only one we know of that has been published is for a manganese-molybdenum steel approximating NE8442 in composition (except that manganese is above the 1.30 to 1.60% specified range) determined at the laboratory of the Climax Molybdenum Co. and published in *Metal Progress* for December 1941, [reproduced to small scale, without micros, in an adjoining column]. It is to be expected that curves for the other NE steels will show a displacement to the right at the "nose" which is commensurate with the hardenability of the steel, and that they will show a "bulge" in the 900 to 1200° F. region, particularly in the "end-of-transformation" line, which will depend in magnitude upon the chromium and molybdenum content of the material. They should resemble the curves for S.A.E. steels of similar carbon content, similar hardenability, and composed of elements which influence the shape of the curve in the same manner as the elements in the NE steel. Certainly, none of them should exhibit any new or unusual behavior which would make them respond to heat treatment in a manner essentially different from the old and well known steels they are intended to replace.

SHOP PERFORMANCE OF NE STEELS

BY GLEN C. RIEGEL
Chief Metallurgist
Caterpillar Tractor Co.

IN ALL PROBABILITY, the engineers and metallurgists who have to cope with the present conditions of stringency in both carbon steel and its common alloys, are anxious to learn what has been the experience of others under the same circumstances.

Having advocated, as early as October 1938, the use of residual alloys in steel manufacture for application in our products requiring deep hardening steels, Caterpillar Tractor Co. quickly began the testing of mill heat quantities of the NE steels even before they had been coded with NE symbols. Our first three mill heats were on order the day after the attack at Pearl Harbor. Since that time, our firm has consumed, in various items of its product, in excess of 60 mill heats of NE alloy steels. (Through August, 1942, a survey showed that there had been made a total of approximately 125 mill heats of NE alloy steels throughout the country.)

We have applied the following types as alternates for the standard S.A.E. compositions: NE8024, 8447, 8620, 8630, 8724, 8739, 8744, 8749, 8817, and 9460. All of these mill heats were subjected to the Jominy or end-quench test, tension test, notched bar impact test (generally the keyhole Charpy type), cold bend test, and production tests of forging, annealing, machining, hardening, and the accompanying evaluations of distortion.

NE8024 (Mn-Mo) was used in place of the former S.A.E. 3115 (Ni-Cr). Its annealed hardness ranged from 143 to 170 Brinell. Little distinction between the machinability of this new material and that of the former S.A.E. steel could be noticed. Hardness as-quenched on carburized specimens ranged from Rockwell C-57 to 65; hardness when tempered at 360° F. for one hour ranged between C-57 and 61.

Much difficulty was encountered with NE8447 when it was hot rolled to shafting sizes; it was then too hard to shear well, the Brinell hardness being as much as 363. This analysis also gave trouble with quench cracking when oil hardened; we were finally compelled to time-quench spline shafts in hot oil. The physical properties after tempering to 800° F. were comparable to those obtained from S.A.E. 3250 (Ni-Cr). When tempered at 1000° F. the Brinell hardness was 302 to 341 and when tempered at 1180° F. the hardness was about 269. For these reasons, we have been reluctant to use the high manganese, higher molybdenum combinations of the NE steels. Series 8200 to 8500 have therefore disappeared from our specifications, both on account of the difficulty in hardening from the finishing temperature in hot rolling or forging, and also because of the high content of strategic molybdenum. As a matter of fact, NE8447 with which we worked has been dropped from the latest list of available steels, 8442 being the highest carbon available, and it is recommended only for large sections.

The 8600 (Ni-Cr-Mo) series has proved very satisfactory, NE8620 being an excellent alternate for S.A.E. 4615 or 4620 (Ni-Mo). The machinability is equally good and the hardness of carburized parts, as quenched, ranged from C-57 to 67, the latter being somewhat harder than we obtained on the S.A.E. 4615 and 4620, as quenched. When tempered to 400° F. the hardness range was Rockwell C-57 to 60. NE8630 has also fulfilled the requirements formerly specified for S.A.E. 4130 (Cr-Mo); in fact, it showed higher notch toughness and cold bend at Rockwell C-50 than either S.A.E. 4130 or 3130 (Ni-Cr).

NE8724 (Ni-Cr-Mo) has been employed as an alternate for S.A.E. 4820 (high Ni-Mo). Our first experiments with these new analyses led us to the conclusion that slightly higher molybdenum was required for the same penetration of hardness and core properties of heavy-sectioned gear teeth. Accordingly, we have adopted a modified practice which tends to keep the molybdenum near the maximum specified for this grade (0.20 to 0.30%) in order to be interchangeable with S.A.E. 4820 steel in our applications. Annealed hardness of NE8724 ran from 143 to 187 Brinell, but when its annealed hardness became softer than 156 the machinability became poor — that is, poor finish was encountered on gear teeth made on Gleason and Fellows shapers. In the range of 163 to 187 Brinell, the machinability was found to be superior to S.A.E. 4820. The hardness of this steel after carburizing and quenching ranged between Rockwell C-57 and 67. After tempering at 400° F. the hardness ranged between C-57 and 62. Slightly more distortion was encountered on this NE grade than was experienced on S.A.E. 4820 due, possibly, to the higher hardening temperature.

NE8739 has been used as an alternate for S.A.E. 3140 (Ni-Cr) and has given an excellent response, both in heat treating and machinability. NE8744 has been used as an alternate for S.A.E. 3240 (Ni-Cr), 2340 (3½% Ni) and 2345. When the manganese is kept toward the middle to the high side of the specified range (0.70 to 0.90%) the hardenability as measured on the Jominy end-quench test is equivalent or superior to either of

the S.A.E. steels mentioned. Notch toughness and yield strength in the same hardness range show no unfavorable comparisons with the S.A.E. 3240, but are slightly below those of the S.A.E. 2345.

In all of these applications, it might be cited that notch toughness tests were conducted at both +75 and −20° F., and are based on the foot-pound values derived from the keyhole type of Charpy specimen. Rarely did the values drop more than 25% at −20° F. as compared with those obtained at +75° F. It also should be said that all of the steels discussed were made to fine-grained practice, and measured A.S.T.M. grain size 5 or finer.

Of the few heats of NE8749 with which we have had experience, the annealed hardness ranged from Brinell 207 to 217. Machinability in the annealed and tempered state was almost identical with that of S.A.E. 4150 (Cr-Mo). Hardness as quenched in ½ to 2-in. sections ranged from Brinell 555 to 601. The following hardnesses were obtained after one hour at tempering temperature:

700° F.	Rockwell C-47 to 48
820° F.	Rockwell C-41 to 44
900° F.	Brinell 363 to 388
1140° F.	Brinell 269 to 277

In conclusion, it should be pointed out that the cumulative effect of proper percentages of small additions of alloys enhances steel by heat treatment to such an extent that at least half of the alloy formerly used under the old S.A.E. compositions can undoubtedly be saved and give steels which, by every laboratory and shop means of appraisal, are substantially equivalent to the older steels. While service experience will take much longer to accumulate, we have no doubts at all on this score.

Fixture For End-Quench Test Mounted Conveniently Between Small Furnaces. Note that water jet hits lower end of specimen only, and sprays out sideways. (Courtesy Joseph T. Ryerson & Son, Inc.)

PROPERTIES OF NE STEELS AT ROOM AND SUBNORMAL TEMPERATURES

BY JOSEPH H. JONES
Central Alloy Division
Republic Steel Corp.

THE METALLURGICAL ASPECTS of NE steels are improving daily. We are already doing that which seemed impossible only a short time ago and have found these new steels with minor amounts of chromium, nickel and molybdenum are capable of fulfilling every reasonable expectation. In many cases they have successfully replaced such types as S.A.E. and A.I.S.I. 2512, 4320, 4340 and other high alloys. Mr. Riegel has just testified as to his broad experience in this direction. Success may be partially due to a reserve of knowledge and experience built up in this country which is equivalent to a sizable amount of alloy in our constructional steels. Many who draw on this reserve fail to fully appreciate its worth.

The best engineer I ever knew once said that when a unit of knowledge is put into the design or fabrication of a mechanical unit, a unit of material or weight can be taken out. American engineers have been contributing knowledge resulting in better designs, machine tools, and inspection facilities, and the manufacturing departments, including steel makers, have contributed precision and uniformity to a point where it is now apparent that designs, materials, and fabricating processes have been improved to a far greater extent than weight or alloys have been taken out. Or, putting it another way, we have improved designs and processing procedure to the extent that we now have a dividend coming. Thus, the alloy content of the steel can, in many cases, be reduced without harm. This undoubtedly is partially responsible for the success of the lean NE analyses in replacing S.A.E. high alloy grades.

Republic Steel Corp.'s laboratory has done considerable investigation on the actual physical properties of NE steels at normal and subnormal tempera-

tures, especially the Ni-Cr-Mo grades (NE8600, 8700 and 8900 series) both oil hardening and carburizing. Preliminary figures on six heats in these three groups were printed in *Metal Progress* for June 1942. We have also tested one heat of 9430. The physical properties developed are comparable to those of the S.A.E. or A.I.S.I. grades they are intended to replace.

This is not surprising when we remember that the NE steels are fine-grained steels produced by the best alloy practice known to the industry, and that they were designed to equal the hardenability of the grades they are to replace. When this is accomplished it is interesting to note how closely the physical properties match the pre-war steels. This is especially true with oil hardening grades quenched and drawn back to around 200 to 450 Brinell hardness. (Incidentally this hardness range covers a wide field of application for oil hardening steels.) Little trouble should be encountered in changing from an old alloy to an NE steel if it falls in this hardness range, because the physical properties follow the tensile strength closely, and tensile strength is determined chiefly by hardness in this range.

It is granted that a high nickel steel will probably have better impact resistance at high hardness than a carbon steel of the same hardness, but the NE steels are not carbon steels, and the advantage of high nickel is not as great as might be expected even at 555 Brinell hardness. To bring out this point we have compared the physical properties of NE9440, 8739 and 9540 with S.A.E. 4145, 4645 and 3245, all treated in 0.530-in. and tested in 0.505-in. round tensile pieces and 0.394-in. square and notched Izod test bars. All were oil quenched from optimum temperature and drawn at 400° F. to approximately 555 Brinell. Values for the S.A.E. steels were taken from "Possible Alternates for Nickel, Chromium and Chromium-Nickel Constructional Alloy Steels", published by American Iron & Steel Institute as No. 5 in the series of "Contributions to the Metallurgy of Steel", and represent average manufacturers' values. (See Table II.)

These values do not indicate any great difference between the six different grades when tested at approximately 555 Brinell hardness, which is about their full hardness. Table III compares oil hardening Cr-Ni-Mo NE grades with A.I.S.I. and S.A.E. analyses at 300 and 400 Brinell.

Low temperature impact results on the NE grades (Table IV) show them to compare favorably with the older steels when quenched and drawn to approximately 400 Brinell hardness. Conventional S.A.E. steels gave impact values of 8 to 19 ft-lb. at −50° F., and the NE steels gave 12 to 20 ft-lb. at −65° F. While this indicates a slight margin in favor of the NE steels, these are individual heat results and not averages; however, the figures at least indicate that no great difference is

Table I — Analyses and Critical Temperatures of Commercial Heats Tested

NE Steel	Check Analysis								Critical Temperatures; ° F. *(a)*			
	C	Mn	P	S	Si	Ni	Cr	Mo	Ac_1	Ac_3	Ar_3	Ar_1
8620 *(b)*	0.19	0.80	0.015	0.015	0.23	0.46	0.52	0.22	1340	1530	1415	1270
8630	0.30	0.80	0.014	0.015	0.25	0.42	0.49	0.22	1350	1470	1360	1220
8640	0.43	0.85	0.016	0.013	0.29	0.41	0.44	0.16	1350	1410	1270	1210
8739	0.41	0.86	0.015	0.019	0.31	0.46	0.47	0.26	1350	1450	1300	1180
8749	0.54	0.83	0.015	0.015	0.23	0.46	0.52	0.27	1340	1420	1240	1210
8817	0.19	0.86	0.013	0.015	0.29	0.48	0.49	0.35	1380	1520	1420	1300
8949	0.49	1.10	0.018	0.015	0.27	0.52	0.51	0.38	1350	1420	1270	1280
9420	0.21	0.95	0.016	0.010	0.53	0.26	0.38	0.15	1340	1510	1390	1270
9440	0.41	1.13	0.015	0.010	0.50	0.32	0.31	0.13	1350	1425	1290	1190
9540	0.41	1.32	0.015	0.011	0.48	0.42	0.63	0.17	1360	1450	1320	1200

(a) Heating and cooling rate is 250° F. per hr. Ar_3 and Ar_1 points should not be used in annealing cycles.
(b) Or low 8720.

Table II — Equivalence of NE and S.A.E. Steels in Fully Hardened Condition

Steel	Nominal Composition					Tensile Bars					Izod Bars	
	Mn	Si	Cr	Ni	Mo	Ultimate	Yield	Elong. (2 In.)	Reduction	Hardness	Ft-Lb.	Hardness
NE9440	1.00	0.50	0.30	0.30	0.12	298,000	283,000	9.5	30.9	555	14, 16	555
NE8739	0.80	0.25	0.50	0.50	0.25	282,500	260,000	8.5	29.2	555	7, 7	555
NE9540	1.35	0.50	0.50	0.50	0.20	295,500	272,500	9.5	32.5	555	21, 22	555
S.A.E. 4145	0.90	0.25	1.00	....	0.20	270,000	235,000	...	28.0	555	8	555
S.A.E. 4645	0.70	0.25	....	1.80	0.25	268,000	230,000	...	38.0	534	16	555
S.A.E. 3240	0.50	0.25	1.00	1.80	....	274,000	240,000	...	37.0	555	11	555

to be expected between the old and the new steels at low temperatures.

There has been some question relative to the effect of the high silicon content on impact figures in the 9400 and 9500 series. Our tests to date have not shown brittleness on these grades with the exception of quenched samples drawn at 600° F., which show a slight drop in impact values similar to S.A.E. chromium steels when drawn at this temperature. It is recommended that this range be avoided in tempering or drawing, just as it was on 5140 and similar analyses. Since there is so little occasion to draw at 500 to 700° F. this limitation should not constitute a serious objection to the analysis.

One final point: In making substitutions I would again emphasize the recommendation that the suggested equivalents, as listed by the American Iron & Steel Institute, should be tried, rather than go to a steel with a higher carbon content. Otherwise excessive hardenability will lead to unnecessary trouble in fabrication.

Table IV — Notch Toughness (Ft-Lb.) of Steels at Sub-Zero Temperatures

Steel *(a)*	Temperature of Test				Hardness of Pieces
	0° F.	−25° F.	−50° F.	−65° F.	
NE 8640	18.0	13.5	....	12.4	401 to 415
NE 8739	27.2	24.4	....	20.5	401 to 415
NE 8749	22.0	14.1	....	15.8	415 to 429
NE 8949	19.2	16.9	....	20.5	429 to 429
NE 9430	11.0	13.0	....	12.0	388 to 401
NE 9440	18.0	19.2	....	14.7	401 to 401
NE 9540	16.3	15.8	....	18.6	388 to 401
A.I.S.I. 2345	15.5	14.5	17.5	....	407
A.I.S.I. 3145	7.0	10.0	4.0	....	429
A.I.S.I. 4065	13.0	11.5	10.5	....	444
A.I.S.I. 4145	15.0	13.0	11.5	....	407
A.I.S.I. 4150	10.0	7.0	8.0	....	429
A.I.S.I. 4340	21.0	20.0	18.0	....	415
A.I.S.I. 6150	22.0	20.5	19.0	....	387

(a) NE steel samples were quenched and drawn to approximately 400 Brinell in finished state. 45° Vee notch, 0.079 in. deep.

Table III — NE and A.I.S.I. Steels Compared at Hardnesses of 300 and 400 Brinell *(a)*

Steel	Tensile Bars					Izod Bars	
	Ultimate	Yield	Elong. (2 In.)	Reduction	Hardness	Ft-Lb.	Hardness
	Oil Quenched and Drawn in 1-In. Rounds to About 300 Brinell						
NE 8640	144,500	121,000	16.3	46.3	302	43, 45	302
NE 8739	148,500	132,000	16	57.3	321	49, 50	302
NE 8749	145,000	127,500	17	53.3	311	54, 54	321
NE 8949	151,000	133,500	18	57.3	321	54, 55	302
NE 9440	156,500	144,500	16	53.4	302	36, 38	311
NE 9540	151,500	136,000	16.5	51.9	321	47, 48	302
A.I.S.I. 2345	140,000	130,000	..	59	300±	40	300±
A.I.S.I. 3145	150,000	127,000	..	55	300±	47	300±
A.I.S.I. 3240	145,000	121,000	..	58	300±	58	300±
A.I.S.I. 3340	150,000	130,000	..	55	300±	50	300±
A.I.S.I. 4140	155,000	130,000	..	59	300±	55	300±
A.I.S.I. 4340	150,000	129,000	..	60	300±	73	300±
A.I.S.I. 4640	148,000	125,000	..	57	300±	45	300±
A.I.S.I. 5150	150,000	136,000	..	59	300±	55	300±
A.I.S.I. 6140	145,000	136,000	..	56	300±	74	300±
	Oil Quenched and Drawn in 1-In. Rounds to About 400 Brinell						
NE 8640	203,200	171,500	11.0	40.2	415	13, 15	401
NE 8739	200,500	179,000	10.5	46.3	415	20, 21	415
NE 8749	205,000	183,500	12.0	41.9	415	16, 17	415
NE 8949	192,000	172,500	13.0	47.8	415	15, 15	415
NE 9440	199,500	179,500	12.5	43.4	388	15, 17	375
NE 9540	183,000	168,000	12.0	49.2	401	21, 23	388
A.I.S.I. 2345	195,000	180,000	....	44	400±	18	400±
A.I.S.I. 3145	208,000	180,000	11.0	43	400±	11	400±
A.I.S.I. 3240	200,000	176,000	....	47	400±	21	400±
A.I.S.I. 3340	219,000	188,000	14.5	48	400±	14	400±
A.I.S.I. 4065	196,000	175,000	....	38	400±	..	400±
A.I.S.I. 4140	215,000	185,000	10.5	45	400±	11	400±
A.I.S.I. 4340	205,000	185,000	14.0	51	400±	14	400±
A.I.S.I. 4640	196,000	178,000	....	49	400±	23	400±
A.I.S.I. 5150	200,000	175,000	....	49	400±	17	400±
A.I.S.I. 6140	195,000	185,000	12.0	52	400±	18	400±

(a) In this and other tables, results are for single heats of NE steels, as made and tested by Republic Steel Corp. Values for A.I.S.I. steels were scaled from diagrams contained in "Contributions to the Metallurgy of Steel", No. 5, published by the American Iron & Steel Institute.

CARBURIZING GRADES OF NE STEELS

BY T. A. FRISCHMAN
Chief Metallurgist
Eaton Mfg. Co., Axle Division

DURING normal times any new steel required a lengthy experimental and development stage, so long that they took five to ten years to reach wide popularity, and would be referred to even then as "newcomers". With this fact in view, the NE steels were just about formulated overnight. Actually, however, their analyses were based on sound reasoning based on experience with the more highly alloyed steels, and warranted releases involving large tonnage as soon as physical properties were checked on small heats from induction furnaces.

The manganese-molybdenum steels of the NE8000 series with manganese over 1.00% are not really new. They had been used long before this emergency, with deviations in manganese and molybdenum contents. They merely received a new name and became more conspicuous in a great hurry. While the carburizing grades still are not looked upon with any too great favor, particularly in severe service, the general heat treating procedure for this group, both carburizing and oil hardening types, was not much of a problem. Field results could be fairly well foretold in advance.

On the other hand the chrome-nickel-molybdenum varieties comprising the NE8600, 8700 and 8800 series presented a different problem, especially in the carburizing grades. They should, upon the basis of chemical composition, occupy a position between the former high nickel steels and the first substitute chromium-molybdenum and chromium-vanadium types. That this is actually so, as far as case characteristics and processing in the shop are concerned, becomes all the more apparent with each passing day.

These new steels might be likened to an offshoot of the familiar S.A.E. 4320 steel, but with 1.25% less nickel and slightly more manganese. Taking this much nickel from S.A.E. 4320 steel (and even more from S.A.E. 4820) and repaying it with 0.50% chromium would naturally involve some changes in the metallurgical characteristics. Likewise if they are substituted for the familiar S.A.E. 4620 steel, some molybdenum and approximately 1.25% nickel has been replaced with 0.50% chromium to bring about the NE8620 steel. These changes in chemistry should raise the upper critical point, especially of the low carbon carburizing varieties. This actually was found to be true, the NE8600, 8700 and 8800 series steels requiring hardening temperatures between 1525 to 1550° F. to harden the core fully as compared to the range of 1450 to 1500° F. for the steels containing much more nickel. In this respect they follow the chromium-molybdenum and chromium-vanadium types resorted to in many instances when the nickel steels were first curtailed.

Just what effect the decrease in nickel has on the carburizing characteristics has occupied the attention of many. One fact now is certain and is heartening: The carbon content in the extreme outer portion of the case does not become excessively high in comparison, for instance, with S.A.E. 4620. Available data from several sources on samples, pot carburized with high percentage coke-charcoal compounds, indicate that the NE8620, 8720 and 8817 steels will have approximately 0.05 to 0.08% higher carbon content in the first 0.005 in. of depth than the familiar S.A.E. 4620 steel. This difference naturally increases when the same comparison is made with such higher nickel steels as S.A.E. 2317, 4820 and 2515, which generally have relatively low carbon at the extreme surface.

This differential in carbon concentration in the outer portion of the case becomes somewhat more when the NE steels are gas carburized. In general, gas carburizing produces a higher carbon case, especially near the surface, than carburizing with solid compounds at equivalent carburizing temperatures. Of importance, however, is the fact that the carbon content at the surface of the case with the NE8600, 8700 and 8800 carburizing steels will be lower than that obtained with S.A.E. 4120 or 6120 steel when carburized under identical circumstances. Though this is apparent, the total case depth is not necessarily greater; in other words, the inner portions of the cases approach similarity as the core material is reached.

In one series of our tests, samples of S.A.E. 4620 steel and NE8720 steel were carburized simultaneously in the same pot, and another set was carburized simultaneously in a gas carburizing furnace. The pot-carburized 4620 showed 1.14% carbon in the first 0.005 in. as against 1.18% carbon in NE8720 steel. At 0.025-in. depth the S.A.E. 4620 sample analyzed 0.80% carbon and the NE8720 was 0.84%. At 0.050 in. the carbon content was the same for both steels, namely, 0.38%. The gas carburized samples showed virtually the same relationship except that there was a somewhat wider spread between the carbon contents at a given depth for the two steels.

Available data thus far have shown no appreciable difference between the carburizing speeds of NE8620, 8720 and 8817 steel. *(Cont. on p. 98)*

HEAT TREATING FOR MACHINABILITY

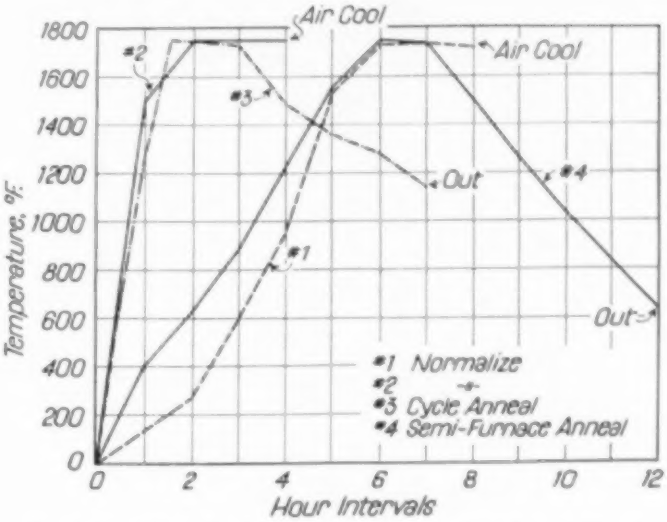
BY L. E. WEBB
Metallurgist, Frost Gear & Forge Division
Clark Equipment Co.

"MACHINABILITY" covers a rather large territory. Conditions and requirements in one shop, when compared with another, may vary to such a degree that it often becomes necessary to revise standard heat treating practices in order to meet the requirements. So some limitation of the scope of these remarks is necessary, and inasmuch as approximately 95% of our work is with the carburizing or low carbon alloy grades, this talk will be confined to our experience, as a manufacturer of truck and tractor gears and forgings, with NE steels of such character.

So, suppose we consider some two or three heats each of the NE8620 and 8722 nickel-chromium-molybdenum grades. The chemistry and hardenability of these heats along with the normalized and annealed hardness values are listed in Table I.

In studying the chemistry of these heats you will note that the carbon contents of the 8620 grades are the same. There is a variation of some 12 points in the manganese, a negligible amount in the nickel and chromium. We also have a nine-point variable in molybdenum content, namely, 0.16 to 0.25%. All three heats are of the fine-grain type. The data given on hardenability pick out the lower chemistry heat, and seem to indicate that the alloying elements will have some effect.

While we are considering these 8620 heats, let us look at the normalized and annealed hardness values obtained from actual production cycles on actual forgings. You will note that, as annealed, there is very little difference in the resultant hardness of these three heats; however, when the steels are tested as normalized we find that the third heat is somewhat harder. In reviewing the chemistry of that heat we find a noticeable difference in the manganese and molybdenum contents. That could be the reason.



Heat Treating Cycles Used for Gear Forgings; No. 1 and 4 in Electric Counterflow Furnaces, and No. 2 and 3 in Continuous Furnaces, Fuel Fired

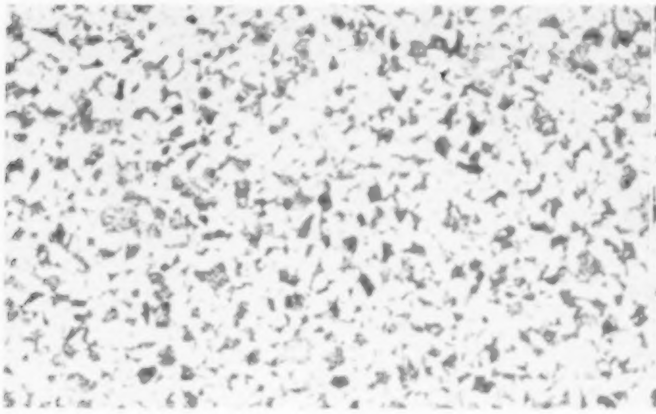
Now, let us consider the last two heats shown. As you see, they are of the 0.25 carbon variety. The 8722 specification calls for 5 points more molybdenum than 8620, the range being 0.20 to 0.30% rather than 0.15 to 0.25%. This did not show up, actually. Comparing the two 8722 heats, there is a differential of 12 points of manganese, and the hardenability seems to vary with the chemistry. In comparing the normalized and annealed hardness values of these two heats, it is found that the heat with lower chemistry anneals out at a very reasonable hardness of 159 Brinell. The normalized hardness shows 187 Brinell, which we consider as top side.

The normalized hardness of the last heat shown in Table I is considerably higher, although

Table I — Data on Five Heats Tested

Part No.	Steel Type	Composition								McQuaid-Ehn Grain Size	Hardness Tests		Normalized		Annealed	
		C	Mn	P	S	Si	Ni	Cr	Mo		Hardenability (a)	End-Quench at 1/16 In.	Hardness	Structure	Hardness	Structure
4940	NE8620	0.20	0.80	0.018	0.020	0.25	0.52	0.50	0.21	7 to 5	302	C-32	156	Fig. 1	143	Fig. 2
5347	NE8620	0.20	0.75	0.018	0.026	0.27	0.45	0.49	0.16	6 to 8	255	C-25	159	Fig. 1	149	Fig. 2
4968	NE8620	0.20	0.87	0.018	0.021	0.30	0.47	0.48	0.25	5 to 8	302	C-32	179	Fig. 3	149	Fig. 4
5348	NE8722	0.25	0.79	0.020	0.030	0.22	0.53	0.50	0.23	6 to 8	321	C-35	187	Fig. 5	159	Fig. 6
5349	NE8722	0.25	0.91	0.019	0.020	0.26	0.53	0.56	0.24	6 to 8	388	C-40	223	Fig. 7	170	Fig. 8

(a) Frost standard: Heat a 1-in. cube to complete solution (austenite), quench in oil at 70° F., mildly agitated. Cut cube in half and Brinell center.



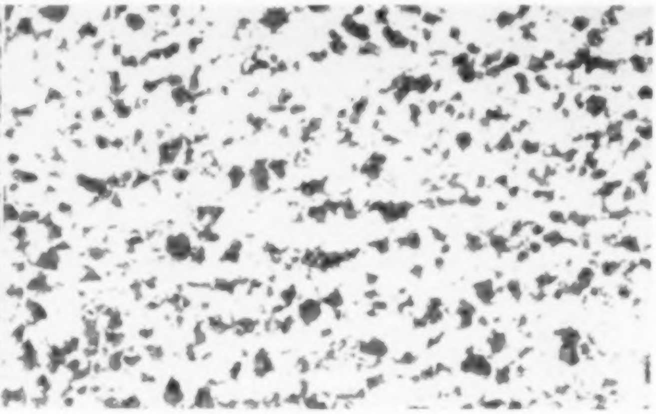


Fig. 1 — Normalized, 156 Brinell Fig. 2 — Annealed, 143 Brinell

NE8620 Heats on Low Side of Analysis

it anneals out rather well. Again, I wonder whether or not certain chemical elements might be contributing to such results.

The normalizing and annealing cycles used to produce the results just referred to are shown in the diagram on page 87. Time-temperature curves No. 1 and 4 were produced in an electric, return counterflow furnace, while No. 2 and 3 were produced in a fuel-fired, straight pusher type, continuous furnace. On these heats we are using a top temperature of 1750° F. to produce satisfactory structures for machinability, whether it be an annealing or a normalizing heat treatment. The amount of time held at temperature was arbitrarily set at not less than 1 hr.

Although we refer to curves No. 1 and 2 as "normalizing cycles", we prefer to call No. 3 a "cycle anneal" and No. 4 a "semi-furnace anneal".

With equipment that is flexible enough, you can readily see that a vast saving in time and increase in production can be had by proper adjustment of the cycle, and still produce satisfactory results. For example, NE8620 material will generally anneal at 1700 to 1750° F. with a semi-furnace cool of approximately 250° F. per hr. (cycle No. 4) or, if equipment is available so that you can obtain a cycle anneal (cycle No. 3) this also will give a microstructure that will produce satisfactory finish and tool life on spiral bevel gear cutting or similar types of cutting. Should you desire slightly harder material for machining, the normalizing treatment will usually help. A Brinell hardness range of 143 to 163 can be obtained from the anneal, while a range of 156 to 179 can quite often be obtained from normalizing.

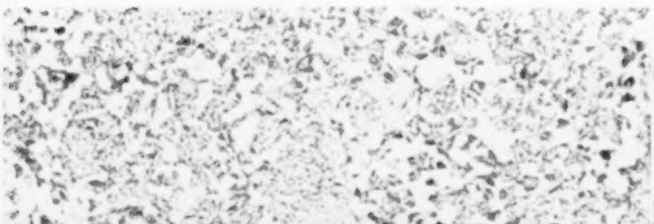
Our general practice has been to normalize the NE8620 and anneal the NE8720 when used for transmission gears that are cut on shapers, hobbing machines or gear shaving equipment.

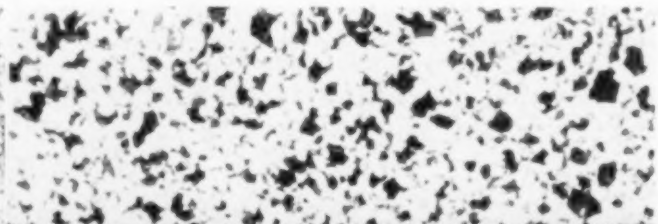
When the chemistry of NE8722 is on the high side it is quite often necessary to cycle anneal, using 7 hr. with the No. 3 curve shown. Otherwise, a satisfactory job of normalizing can be done in pusher furnaces taking only 4 hr. Many variations can be built around these curves to produce desirable structures for machining. (Feeds and speeds are, of course, very important where tool life and finish are involved. Proper grinding facilities and a knowledge of how to use a good tool are also pertinent requisites.)

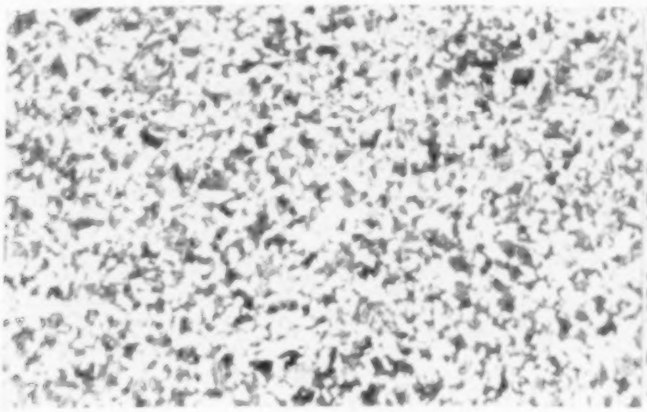
In order to determine what materials can be put through the shorter cycles No. 2 and 3, one must know the materials — their chemistry and hardenability — and secondly the peculiarities of the part to be manufactured. This cannot be emphasized too much. If we determine, for instance that the chemistry or hardenability of an NE8620 is on the high side, we will recommend to the heat treating department that an annealing cycle be used, unless the particular part does not warrant such a treatment. Again, if the hardenability or chemistry of an NE8722 is low, and the part to be manufactured carries certain requirements, we may suggest that the part should be normalized.

NE8620 Heat on High Side of Analysis

Fig. 3 — Normalized, 179 Brinell Fig. 4 — Annealed, 149 Brinell







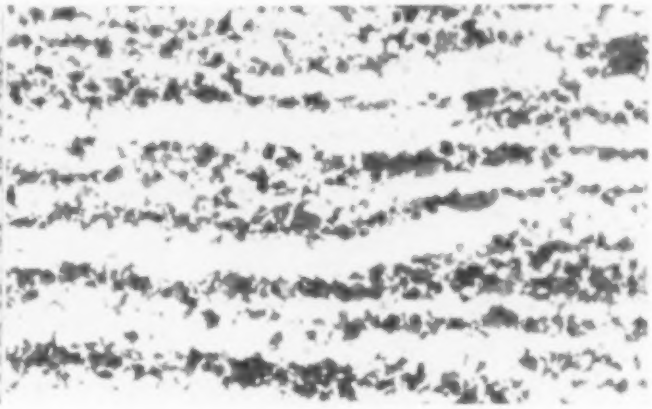


Fig. 5 — Normalized, 187 Brinell

Fig. 6 — Annealed, 156 Brinell

NE 8722 Heat at About Middle of Specification

Return now to Table I, which correlates the chemistries and hardness values, and I will show some of the corresponding structures.

Figure 1 shows the normalized structure of the first NE 8620 heat (Part 4940). It is quite uniform and has a blocky appearance, with a Brinell hardness of 156. Figure 2 shows the same material as annealed. Here again, we have the blocky appearance; the pearlite is in the sorbitic condition. Note a tendency toward banding. Brinell hardness is 143.

Normalized and annealed structures of the second NE 8620 are practically identical to the previous one. (All micros are at 100 diameters.)

Figure 3 is a normalized structure of the third NE 8620, whose Brinell hardness is 179. This structure is definitely acicular, and I would suspect that we might have some trouble on the machine line. You will recall that the chemistry of this heat is on the high side. Figure 4 shows the annealed structure of the same heat. Brinell hardness is 149. It can be likened to the two previous annealed samples, being blocky and sorbitic; however, there is little trace of banding.

The moral of these remarks is that, even though the analysis of the complex alloy steels seems to be in line, it is necessary to *know your material* before planning subsequent operations.

In showing the last four figures I hope to bring out some of the extremes in microstructure one might encounter from normalizing or annealing of heats with slightly higher chemistry.

Figure 5 is NE 8722, part No. 5348. Normalized its Brinell hardness is 187. Although it is somewhat blocky in appearance there seems to be a tendency toward acicular markings in the ferrite. This probably would not machine too well. Figure 6 is the annealed structure of the same material. It is definitely banded, although pearlite is in blocky chunks. The cool out was too slow. Its Brinell hardness is 156.

Figure 7 is the heat with manganese on the high side. Normalizing produces a definite acicular structure and a Brinell hardness of 223. Figure 8 shows the same material annealed and slow cooled. Brinell hardness is 170. Again we have the banding effect with the blocky condition of pearlite grains.

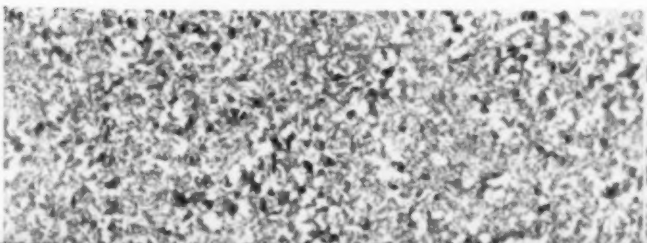
These structures are not as conducive to good machinability as were those shown previously for NE 8620. You can readily appreciate, therefore, the importance of emphasizing control and precision in the heat treating of such materials. Lowering the alloy content necessarily narrows the working ranges.

In conclusion, it seems to me, from our experience so far, that the NE steels are a tribute to the metallurgical profession of this country. These materials have been given a great deal of thought and have been formulated with an uncanny view toward the specific effect of each individual alloying element, in order to build into each type the properties necessary to meet the urgent needs of this country.

NE 8722 Heat With Manganese on High Side

Fig. 7 — Normalized, 223 Brinell

Fig. 8 — Annealed, 170 Brinell



Revised List of National Emergency Alloy Steels

December 17, 1942

Openhearth Alloy and Electric Furnace Alloy Steels

(Blooms, Billets, Slabs, Bars and Hot Rolled Strip)

Designation	C	Mn	P Max.★	S Max.★	Si	Ni	Cr	Mo
			Carbon-Manganese Steels					
NE1330	0.28-0.33	1.60-1.90	0.040	0.040	0.20-0.35			
NE1335	0.33-0.38	1.60-1.90	0.040	0.040	0.20-0.35			
NE1340	0.38-0.43	1.60-1.90	0.040	0.040	0.20-0.35			
NE1345	0.43-0.48	1.60-1.90	0.040	0.040	0.20-0.35			
NE1350	0.48-0.53	1.60-1.90	0.040	0.040	0.20-0.35			
			Carbon-Chromium Steels					
NE52100*C*	0.95-1.10	0.25-0.45	0.025†	0.025†	0.20-0.35	0.35 max.	0.40-0.60	0.08 max.
NE52100*B*	0.95-1.10	0.25-0.45	0.025†	0.025†	0.20-0.35	0.35 max.	0.90-1.15	0.08 max.
NE52100*A*	0.95-1.10	0.25-0.45	0.025†	0.025†	0.20-0.35	0.35 max.	1.30-1.60	0.08 max.
			Manganese-Molybdenum Steels					
NE8020	0.18-0.23	1.00-1.30	0.040	0.040	0.20-0.35			0.10-0.20
NE8442‡	0.40-0.45	1.30-1.60	0.040	0.040	0.20-0.35			0.30-0.40
			Nickel-Chromium-Molybdenum Steels					
NE8613	0.12-0.17	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8615	0.13-0.18	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8617	0.15-0.20	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8620	0.18-0.23	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8630	0.28-0.33	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8635	0.33-0.38	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8637	0.35-0.40	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8640	0.38-0.43	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8642	0.40-0.45	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8645	0.43-0.48	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8650	0.48-0.53	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
NE8720	0.18-0.23	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30
			Silicon-Manganese and Silicon-Manganese-Chromium Steels					
NE9255	0.50-0.60	0.70-0.95	0.040	0.040	1.80-2.20			
NE9260	0.55-0.65	0.75-1.00	0.040	0.040	1.80-2.20			
NE9262	0.55-0.65	0.75-1.00	0.040	0.040	1.80-2.20		0.20-0.40	
			Manganese-Silicon-Chromium-Nickel-Molybdenum Steels					
NE9415	0.13-0.18	0.80-1.10	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9420	0.18-0.23	0.80-1.10	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9422	0.20-0.25	0.80-1.10	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9430	0.28-0.33	0.90-1.20	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9435	0.33-0.38	0.90-1.20	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9437	0.35-0.40	0.90-1.20	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9440	0.38-0.43	0.90-1.20	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9442	0.40-0.45	1.00-1.30	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9445	0.43-0.48	1.00-1.30	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9450	0.48-0.53	1.20-1.50	0.040	0.040	0.40-0.60	0.20-0.50	0.20-0.40	0.08-0.15
NE9537‡	0.35-0.40	1.20-1.50	0.040	0.040	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25
NE9540‡	0.38-0.43	1.20-1.50	0.040	0.040	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25
NE9542‡	0.40-0.45	1.20-1.50	0.040	0.040	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25
NE9550‡	0.48-0.53	1.20-1.50	0.040	0.040	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25
			Manganese-Silicon-Chromium Steels					
NE9630	0.28-0.33	1.20-1.50	0.040	0.040	0.40-0.60		0.40-0.60	
NE9635	0.33-0.38	1.20-1.50	0.040	0.040	0.40-0.60		0.40-0.60	
NE9637	0.35-0.40	1.20-1.50	0.040	0.040	0.40-0.60		0.40-0.60	
NE9640	0.38-0.43	1.20-1.50	0.040	0.040	0.40-0.60		0.40-0.60	
NE9642	0.40-0.45	1.30-1.60	0.040	0.040	0.40-0.60		0.40-0.60	
NE9645	0.43-0.48	1.30-1.60	0.040	0.040	0.40-0.60		0.40-0.60	
NE9650	0.48-0.53	1.30-1.60	0.040	0.040	0.40-0.60		0.40-0.60	

★These limits are for basic openhearth steel. The lowest standard maximum phosphorus or sulphur content for acid openhearth or acid electric furnace alloy steel is 0.05% each.

†These limits are for electric furnace grades; if made in the basic openhearth the sulphur and phosphorus may be 0.04% max. each.

‡For large sections only.

Modifications in this table, approved by representatives of the War Production Board, the Technical Committee on Alloy Steel of American Iron and Steel Institute, and by representatives of the Society of Automotive Engineers, were caused by an unexpected gain in the available nickel. Irrespective of the fact that the 1943 Canadian production will be 50,000,000 lb. greater than in 1940, the average nickel content of scrap has been steadily increasing, due partly to the influx of new nickel steel scrap from ordnance contractors, and partly to conservation measures employed by the steel mills.

Consequently, many alloy steel producers find it virtually impossible to hold the nickel content of some NE 8600 and 8700 series steels below 0.60%, as originally specified. There is not enough carbon steel scrap low in phosphorus and sulphur content for dilution, and the nickel cannot be reclaimed for any other use or in any other manner. A general increase of ten points in the upper limits for nickel is therefore possible.

The NE8700 series has been abandoned except 8720, which has found much favor. These abandoned steels are also rather high in molybdenum (0.20 to 0.30%), now critically short in supply.

To compensate for the 8700 series, the 8600 series with lower molybdenum has had its nickel increased ten points, and the carbon range extended to 0.50% carbon. The new NE8635 to 8650 steels also have higher manganese (0.75 to 1.00%).

BITS AND PIECES

METALLURGICUS' OWN PAGE

HELP! HELP!

SPOT TESTING, to determine quickly and accurately such elements as copper, nickel and chromium in alloys, is particularly timely. Is there, I wonder, such a test for manganese? How to segregate, for example, water hardening toolsteel with 1% carbon and 0.35% manganese from oil hardening toolsteel with 0.9% carbon and 1.5% manganese. My spark tester can pick the right one 9 out of 10 times, but the tenth time certainly caused a headache! If anyone can send in a workable method, there's an ⊕ book of his choice for reward — as, indeed, for any publishable item for "Bits and Pieces."

METALLURGICUS

WHAT IS "DECARB"?

METALLURGICUS' question posed in the November issue might be answered by turning to the definition proposed by the Nomenclature and Definitions Committee of the American Society for Testing Materials. The committee is comprised of representatives of the ⊕, the Society of Automotive Engineers, American Foundrymen's Association, as well as the American Society for Testing Materials. It is proposed that decarburization shall be understood to mean "the loss of carbon from the surface of an iron-base alloy as the result of heating in a medium which reacts with the carbon".

This, of course, is a qualitative or dictionary definition. In addition to a plea for correct use of words, Metallurgicus' brief note last November implied that *methods* for measuring the effect are loosely applied. I have found that, in the types of steel we work with, the amount of decarburization may be determined by macro-etching a polished surface with a 5% solution of nitric acid in alcohol. The decarburized areas will be light; the area not decarburized will be dark. In toolsteel, in addition to difference in color, the decarburized zone may exhibit a grain structure larger in size than the remainder of the cross-section. (EUGENE M. SMITH, Extrusion Division, Aluminum Co. of America.)

CALIBRATING A MICROSCOPE'S MAGNIFYING POWER WITH SHIM STOCK

ON A RECENT RUSH JOB it became necessary to take some pictures at a magnification under conditions not previously established. Since a stage micrometer was not available, a substitute had to be found. After trying several things unsuccessfully this idea was hit upon:

Every machine shop has in its supplies some "shim stock" consisting of narrow strips of very carefully cold rolled brass sheet in several gages, usually 0.002 to 0.015 in. The thickness is very uniform and can be determined very accurately with a vernier micrometer. A small piece of each gage was mounted in bakelite and polished according to usual metallographic practice but was not etched. These polished sections were then projected onto the ground glass of the camera and the bellows length adjusted until the image was of the correct width, as determined with a pair of dividers, to give the desired magnification. (These sections can also be used for calibrating filar micrometers.)

Such a method has one distinct advantage over the use of a stage micrometer; that is, the image of the brass strip is very sharply differentiated from the bakelite mount by the high color contrast, and, hence, is easier to focus properly and measure with dividers than the ruled lines on a stage micrometer. (D. J. MACK, Assistant Professor of Chemical Engineering, University of Tennessee.)

Sorting of Steel

In the January 1942 issue of *Metal Progress* appeared a letter from C. S. Williams, headed "Rapid Sorting of Small Castings" referring to the use of an oscillograph for sorting heat treated ferrous parts from untreated parts. Having recently had occasion to sort out a considerable quantity of alloy steel components heat treated to 135,000 psi. from a number made in mild steel, reference was made to Mr. Williams' letter, but unfortunately the cathode ray tube of our oscillograph was defective.

A very simple apparatus has now been rigged up utilizing a somewhat similar principle but needing only standard radio parts which were available. A photograph of the apparatus in its original form is attached. A sample of the correct material is placed in one coil out in front and the sample being tested in the other coil, the difference in magnetic properties being shown on the cathode ray tuning indicator.

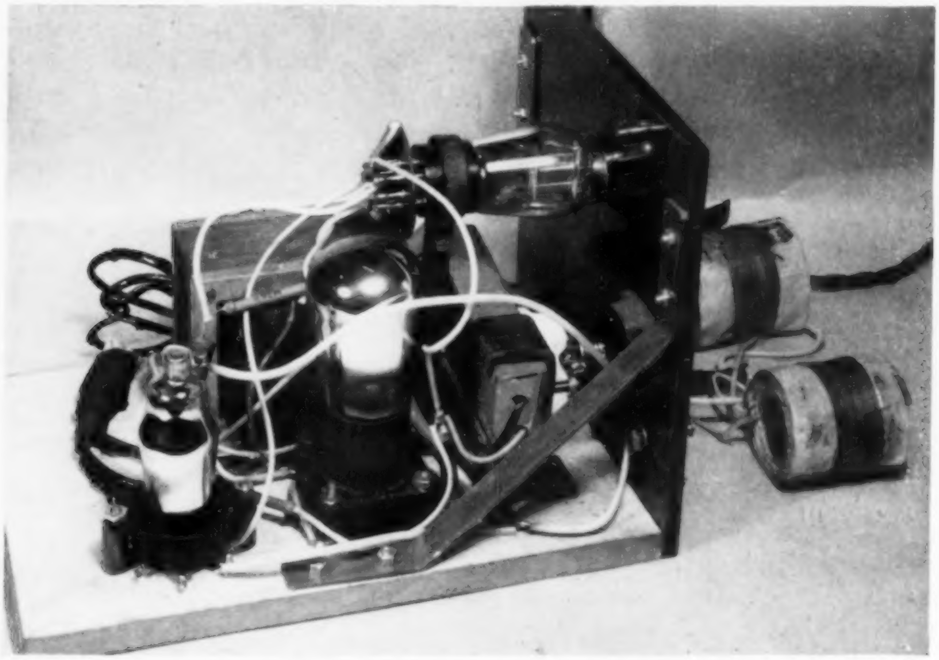
Both test coils comprise double windings, one pair being in series and connected direct to the alternating current mains; the other windings comprise search coils which detect the difference in hysteresis between the two materials. (R. J. Brown, Metallurgist, Morris Motors, Ltd., Coventry, England.)

Twelve Temperings to Harden Austenitic Die

Seldom does a highly austenitic structure remain in a steel after heating and quenching, with the possible exception of high speed steel. However such a structure was encountered in G.M.C. 100-M air hardening toolsteel of the following analysis: C 1.01%, Mn 0.86%, Si 0.38%, P 0.014%, S 0.010%, Cr 5.14%, Mo 1.12%.

The die should have been heated at 1750° F., but due to trouble with the control couple the die was actually heated nearly to 1900° F. It was removed from the furnace, and a fan was turned on it until it was just cool enough to handle *uncomfortably* in the bare hands. It was then tempered at 425° F. for 4 hr. After this complete treatment the hardness was C-30 to 35, but the die was extremely file hard. This, of course, led us to suspect "soft skin", so the die was taken to a large Blanchard grinder but it would not adhere to the magnetic chuck. The evidence now definitely proved the presence of a highly austenitic structure. Further, when checked for size and volume change it was found that the die had shrunk 0.042 in. on approximately 14⅜ in.

We then tempered the die 4 hr. at 500° F. Its Rockwell hardness was still C-30 to 35, but the die had expanded about 0.001 in. After a draw of 900° F. the hardness had jumped to C-32 to 37. Two more draws of 950° F. (cooling to room temperature between heatings) increased the hardness to C-40. Seven successive tempers at 950° F. for 2 hr. finally brought the hardness up to C-58 to 60. The die was then highly magnetic, and it had expanded a total of 0.044 in., being only 0.002 in. over its original dimension of 14.393 in., and was fully transformed. (Stewart M. DePoy, Metallurgist, Delco Products Division, General Motors Corp.)



Assemblage of Common Radio Parts Connected With Twin Search Coils (on Table Top at Right) for Detecting Differences in Magnetic Hysteresis in Unknown Sample and Standard


LYMAN
ANDERSON

SOLDER

(Continued from page 59)

have had better success tinning the iron with a small amount of 30% tin, 70% lead solder, and then applying the tin-less solder to this iron. Frequent tinning is necessary, so a small pot with melted 70-30 solder under zinc chloride cover is a handy adjunct. Use it as a holder for the soldering tool, where it can be constantly immersed when not in use. Even this may be avoided if the soldering copper is previously nickel plated, iron plated, or silver plated.

This solder has a very small freezing range and freezes rapidly behind the iron. This is an advantage in many cases because the solder stays where it is put without flowing too deeply into a crack. So far the authors have had little success with sweating this solder into joints.

We do find that when this solder is used on tin plate, less solder is used per joint than with ordinary solder, and a speed of 24 ft. per min. is readily attained by a good workman.

Cost of Solder

The metals in the alloy of 0.5% arsenic, 12% antimony, balance lead, cost about $8.50 per 100 lb. One per cent arsenical lead was purchased at $7.40 per 100 lb., and lead $6.85. Antimony cost $17.76 per 100 lb. With a cost of 1.5¢ per pound for melting and alloying, this solder would cost about 10¢ per lb. Other costs are approximated in Table III.

Conclusions

1. The best tin-less substitute solder developed so far is an alloy of 0.5% arsenic, 12% antimony, with balance lead.

2. The cost will be about 10¢ per lb.

3. Its melting point is 478° F. which is close to 30-70 solder, which melts at 496° F.

4. The joint strength of six lapped joints averages 8300 psi., which is stronger than 50-50 solder (8100 psi.), or lead-silver alloys.

5. Its solderability is good on tin plate and bare steel, but not good on copper or brass.

6. With special technique a speed of soldering can be had on tin plate which equals that obtained with 30-70 solder.

7. Lead-silver alloys are unsatisfactory, primarily because their high melting point causes an undue amount of oxidation and, therefore, inferior soldering properties.

Finally, the authors wish to thank the Superior Metal Products Co. of St. Paul, and Walter Nelson, its soldering expert, for working with them in developing this new solder.

MALLORY STANDARDIZED WELDING ELECTRODES

Flash Welding Speeds Production of Steel Strip!

Strip steel . . . needed for aircraft assemblies, destroyer smokestacks, "jeep" bodies, Army field kitchens and bomb fins . . . for literally thousands of military and industrial purposes . . . is speeded to war production plants by welding with Mallory Flash Welding Dies.

In one of the world's largest strip mills, the resistance flash welder shown above joins single coils of strip steel to form multiple coils. Major advantages are:

1. *Speedier Production.* It is much faster to "thread" multiple coils through picklers, rolling mill stands and shears than to thread shorter, single lengths of strip.

2. *Greater Uniformity.* The percentage of "off-gauge" and scrap steel is minimized.

3. *Meeting Customers' Requirements.* Many users prefer longer, heavier coils.

Flash welding is the best commercial process for joining strip in steel mills, because the welds are made automatically. Operators are quickly trained. Machine maintenance can be kept to a minimum . . . especially since most flash welders are equipped with dies produced by Mallory, and these dies assure more welds between dressings, a higher total number of welds before replacement is necessary, and thus sounder, more uniform welding.

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RESISTANCE WELDING — P. R. MALLORY & CO. Inc. **MALLORY** — **STANDARDIZED ELECTRODES**

NE STEELS

(*Continued from page 86*)

Carbon concentration can be regulated by any of the means formerly employed, such as altering the composition of the compound, diffusing as in gas carburizing, or — the simplest of all — regulation of the carburizing temperature.

A gratifying characteristic, and one especially welcome to gear manufacturers, is the freedom from skin softness in the NE8600, 8700 and 8800 series carburized steels, a shortcoming that required constant supervision when using S.A.E. 4120, 5120 and 6120. The new steels are much more file resistant, resembling the S.A.E. 4620, 4320 and 4820 steels.

Another characteristic noted thus far is that these new steels seem to resist softening more than some of the former steels when tempered at temperatures around 350 to 450° F. In other words, they must be tempered higher to produce hardness equivalent to the higher nickel steels. This resistance to softening should manifest itself in increased wear resistance in service.

Microstructures of the case and core of these three NE steels resemble the familiar nickel-molybdenum carburizing steels. There is a tendency to form excess carbides, somewhat massive, when the carbon content approaches 1.15% in cases around 0.060 in. deep. (Excess carbides were not found in cases around 0.045 in. deep where the carbon concentration is usually not so high.) If this condition is undesirable, especially in clash gears, a higher tempering temperature might prevent the chipping of tooth ends.

Information obtained to date indicates that these steels do not distort in heat treatment any more than, for instance, S.A.E. 4620 steel, which is good news for the gear makers.

A few tests conducted thus far have indicated that coarser fractures obtain with the new steels, both direct quenched or reheated, in comparison with the former nickel steels, although the fracture is no coarser, and if anything somewhat finer than is obtained with some of the earlier emergency steels. Another of the so-called shop tests is peening the corners of gear teeth to test the malleability of the case. The new steels when so hammered in the direct quenched condition could be deformed as much as the older gear steels without chipping.

Reports from several sources regarding breakdown tests in the field and on laboratory dynamometers have been encouraging so far, which would indicate that the NE steels are adequate for many applications. Their use is rapidly spreading.

Deepfreeze

METAL SHRINKING

Speeds up Production

in Assembling Piston Bushings - and Saves

$3000 to $4000 per Month over Liquid Air

COMPANY NAMES STARTING WITH **O**

increased production

Case Study from the Files of Deepfreeze

The Sub-Zero Method of Shrinking, Testing and Treating of Metals

[DETAILS, FACTS AND FIGURES FURNISHED ON REQUEST]

Data and Part Information

A bronze S.A.E. 64 wrist pin bushing for piston of a Diesel engine.

Size $\frac{3.3190''}{3.3185''}$ outside diam. x 2.022″ long

Inside bore $\frac{3.0005''}{3.0015''}$

Bore in piston for bushing $\frac{3.3135''}{3.3140''}$ diam. on $8\frac{1}{2}$ diam. piston

REQUIREMENTS

To shrink outside diameter of bushing .005″ to permit a slight press fit. This is required to provide metal-to-metal contact for entire length of bushing.

DIFFICULTIES

Diameter of bushing is .0055″ larger than the hole at room temperature. Another type of chilling unit with a maximum temperature of −65° was tried, but the .0025″ to .003″ shrink obtained was too little and caused the bushing to wobble in the hole.

Other Difficulties . . .

Liquid air was too costly, difficult to obtain and required the services of two men. Dry ice also proved impractical and costly.

SOLUTION

The Deepfreeze Cascade Unit—which meets every requirement for shrinkage, speed, accuracy and reduced cost. Material and service delays are eliminated, spoilage is reduced and production is UP.

SAVINGS

It is estimated that the Deepfreeze Cascade Unit saves between $3,000 and $4,000 per month over the use of liquid air.

You Too Can Profit

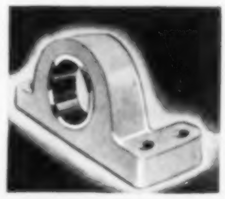
With *Deepfreeze* Sub-Zero Temperatures for Your Metal Working Operations

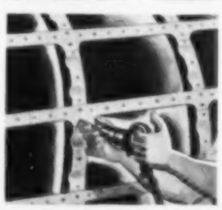
Deepfreeze can serve you in any one, or all three, of the following ways . . .

1 Shrinking of metal at −*100°* F. *to −120° F.* has made it possible to assemble bearings and similar parts requiring a press-fit, by merely slipping them into position . . . eliminates spoilage caused by "pounding" bearings into place . . . saves time caused by delay in replacing bearings . . . saves cost of expensive equipment.

2 Testing of metals at −*100° F.* to −*120° F.* has made it possible to study the reactions of aircraft instruments to stratosphere flying. Aircraft engine lubricants can also be pretested for sub-zero flying. Tests are usually conducted over a 6 or 8-hour freezing period.

3 Treating of metal at −*100° F. to −120° F.* will produce combinations of hardness, strength and ductility not obtainable by ordinary hardening or tempering. For treatment of high-speed steel, temperatures colder than −150° F. are ineffective. Temperatures *warmer* than −100° F. are also ineffective. The Deepfreeze Cascade Unit is capable of maintaining −120° F., making it ideal for the proper treatment of high-speed steel.





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ESTIMATE OF STEEL FOR 1943

DONALD NELSON estimated, in a recent statement issued by the War Production Board on the steel expansion program, that United States' steel production in 1943 will approach twice the combined output of the Axis nations, which is estimated at 50 to 55 million tons of ingots. Steel capacity in the United States is now over 89 million tons, and by mid-'43 will be 97,115,000 tons of ingots, made up of 84,241,000 of openhearth, 6,721,000 of bessemer, and 6,153,000 of electric steel.

The over-all production figures, Mr. Nelson pointed out, do not tell the whole story.

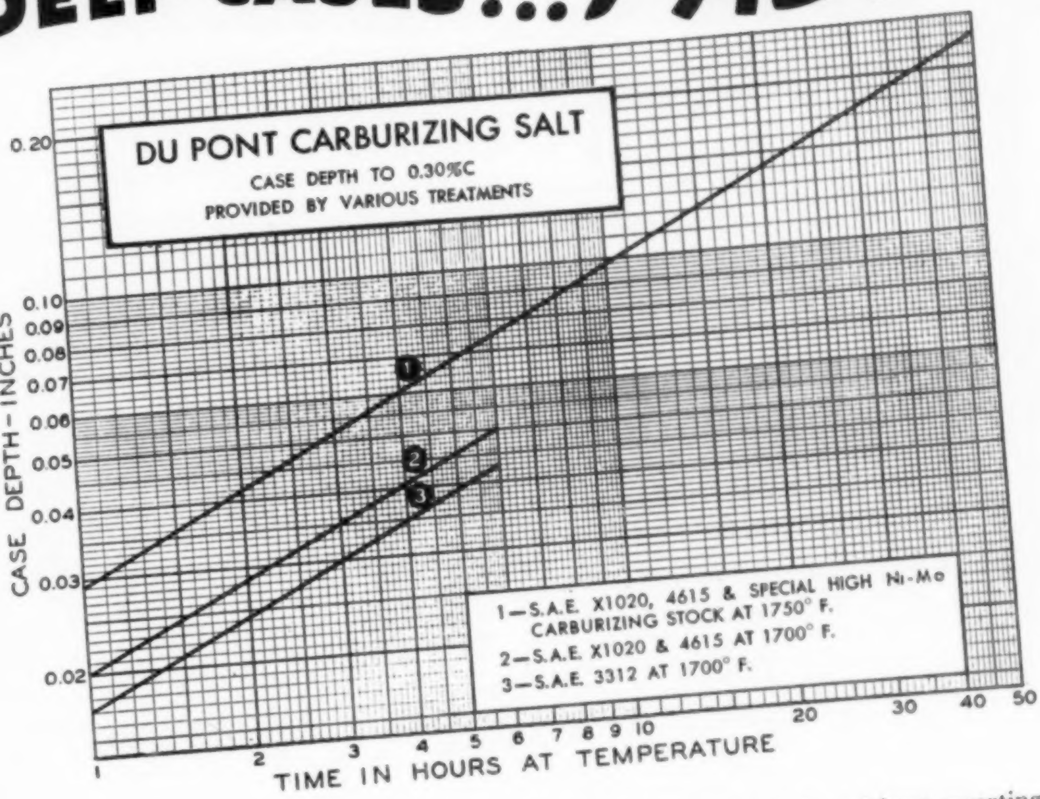
For instance, our alloy steel production has shown remarkable progress. Tonnage is now substantially in excess of 1,000,000 each month, and will increase further next year. We are now producing more than four times as much alloy steel as in the last peacetime peak. Monthly production in 1938 averaged 137,800 tons of alloy steel; in 1939 it was 270,000 tons per month. January of 1942 produced 736,000 tons of alloy steel, and by year's end this was up more than 50% (1,130,000 tons in December 1942). Estimated average for 1943 will be 1,230,000 tons of alloy ingots per month.

Expansion in over-all steel tonnage has also been extraordinary. During the month of December 1937 the American steel industry's production of all grades of steel ingots was less than 1,750,000 tons. During September 1938, at the time of the Munich agreement, it amounted to only 3,000,000 ingot tons. Not until the start of war in Europe in 1939 did production start to climb, but by mid-'43 it will be close to estimated capacity of 8,100,000 tons of ingots monthly. This 8,100,000 tons of ingots will produce about 5,600,000 tons of mill products, the difference being scrap — butt ends, croppings, defectives, and so on, that are immediately returned for remelting.

Likewise in the finishing mill departments conditions are in a constant flux. For example, in January 1942 we produced 750,000 tons of plate and 1,150,000 tons of sheet and strip. In January 1943 we expect to produce 1,110,000 tons of plate and only 830,000 tons of sheet and strip — evidence of the conversion of continuous sheet mills to plate manufacture, and the growing importance of the shipbuilding program.

(Continued on page 102)

DEEP CASES...*FAST*



USE DU PONT CARBURIZING SALT. This carefully balanced composition produces deep, high-carbon low-nitrogen cases (0.10% nitrogen or less in the first 0.004″ of case) at temperatures of 1650° to 1750° F. . . . equivalent, in all respects, to those obtained by pack and gas hardening. At similar conditions of time and temperature, it will produce greater depth of case than can be had from pack hardening.

Baths containing Du Pont Carburizing Salt are stable above 1700° F. Cyanide decomposition is low—about 0.05% per hour at 1725° Work may be quenched directly from the bath, without resorting to reheating. There is also the decided advantage of using a flexible liquid salt bath for deep case operations, rather than a cumbersome, time-consuming pack hardening process.

For deep and shallow cases, du Pont has the right case hardening and carburizing products. Competent metallurgists, in our laboratories and in the field, will be pleased to help you with your problems and in the selection of the proper materials for your specific job. Electrochemicals Department, E. I. du Pont de Nemours & Co. (Inc.), Wilmington, Delaware.

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CYANIDES and SALTS for Steel Treating

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

STEEL FOR 1943

(Continued from page 100)

Of the total expansion of 7,640,000 tons in the openhearth department, new furnaces account for 5,283,000 tons, enlargements account for 634,000 tons, and use of hot metal in place of cold charge is equivalent to 1,723,000 tons of new capacity.

Electric furnace capacity, important in the production of alloy steels, amounted to 3,402,000 tons at the beginning of 1942. During that year, new facilities with a capacity of 970,000 tons were added. Increases amounting to 294,000 tons, resulting from improved equipment and technique, bring the total productive capacity at the end of 1942 to 4,666,000 tons. New facilities to be brought into production by June 1943 will boost the total electric furnace capacity to approximately 6,153,000 short tons of ingots.

No expansion in the capacity for bessemer steel is planned.

Blast furnace capacity has also been largely increased (see *Metal Progress*, July 1942, page 83, for the details of the program). Adequate raw materials have also to be provided, the goal of the present program being:

Iron ore	133,949,000 tons
Coke	80,440,000
Limestone	34,716,000
Pig iron	68,716,000
Recirculating scrap available	27,192,000
Purchased scrap needed	14,386,000

Consumption of iron ore is now running at a rate of 10,000,000 tons a month, and with shipping on the Great Lakes closed for the winter season, the inventory on hand amounts to almost 60,000,000 tons. Construction of new iron and steel plants in the South, West, and on the Pacific Coast, as well as interruption of foreign imports of iron ore (amounting to 2,300,000 tons in a normal year) will call for sizable increases in iron ore production in all American districts, the goal of the present program being

Texas and Missouri	896,000 tons
Eastern	6,160,000
Western	4,144,000
Southern	10,640,000
Lakes	112,109,000
Total	133,949,000

As to coke, the steel industry's own byproduct oven capacity is being enlarged from 50 million tons as of Jan. 1, 1942 to 57 million as of July 31, 1943. This amount available for the blast furnaces will be supplemented by 14½ million tons of coke from merchant byproduct ovens, and 9 million from beehive ovens.

IRON AND STEEL IN NAZI GERMANY★

ONE evident weakness of the German iron and steel industry when the Nazis came to power was its dependency on foreign ores. For instance, in prosperous 1936, the Reich produced 19,200,000 tons of steel but mined only 7,600,000 tons of 30% iron ore. About half the imported ores came from Sweden, the remainder from Lorraine, Spain, and French North Africa.

At that time Hermann Goering was told to make the nation self-sufficient, and he turned to the Salzgitter mines in the Harz Mountains in Central Germany, where enormous low grade ore bodies exist. The original plan was to increase the annual output to 20,000,000 tons ore, containing 6,000,000 tons of iron, and the annual output in other districts to 25,000,000 tons, with 5,500,000 tons of iron content. After the incorporation of Austria, even this plan would produce only about half of the German steel requirements from German ore. (When the war started in Poland only about one-quarter of the iron requirements was mined at home.)

Salzgitter ores are low in iron and contain about 25% SiO_2, and can be smelted only with a large admixture of better ore and with excess lime. High sulphur in the pig iron is removed by soda treatment. The whole process was never justifiable from a cost standpoint; even the military usefulness was more than doubtful from the very beginning. More labor, more coke, and more power are needed for the extraction of a given quantity of Salzgitter iron than, for instance, from Swedish ores.

Despite objections from industrialists and technicians, Goering founded the "Hermann Goering Works" in 1937 for working the Salzgitter ores, and immediately started the construction of huge furnaces with an annual output capacity of at least 4,000,000 tons of pig iron. The district is situated about 150 miles from the nearest coal mining center, the Ruhr. Costs mount due to high railway charges on coke and on the necessary Swedish ores. While the latter can in normal times be shipped to the Ruhr furnaces, via the Rhine, no cheap river transport exists to the Salzgitter district.

Losses in manufacture of raw material, however, are compensated for in profits on sale of manufactured goods and even munitions; these prices are fixed

(Continued on page 114)

★Extracts from special correspondence in *The Engineer*, Oct. 23, 1942, page 342.

NAZI STEEL

(Continued from page 108)

either on the cost-plus principle or according to a special price schedule which leaves a fair profit margin to manufacturers. Iron and steel producers have therefore acquired the manufacturing establishments. Vertical trusts have, as a rule, over-compensated the losses of their iron and steel production by their highly profitable other businesses. The semi-official Hermann Goering Works has extended its sphere of influence even further than any private firm, and has grown into a position unequaled by any other industrial trust in modern European history. With every new territorial gain on the part of Germany, it has acquired new interests in various industrial fields. It is now the sole owner of the Skoda Works and the Bruenner Waffenwerke in Czechoslovakia; it also owns the Austrian Alpine Montan Works, various Silesian collieries, ore mines in Lorraine, and it controls most of the Danubian shipping; it trades in petroleum, and it is one of the leading Continental producers of office equipment. Furthermore, after the occupation of large parts of Soviet Russia, the works "acquired" the right to administer the whole of Russia's mining and heavy industries. Early in 1941, as many as 600,000 workers were employed in works completely owned by the Hermann Goering Trust.

There was a unique chance for Germany to reconsider her iron ore policy after the conquest of France and the Low Countries in the summer of 1940. The acquisition of the minette ore mines of Lorraine, in addition to the smaller, but valuable Luxembourg mines, made self-sufficiency in iron ore a reasonable proposition for the first time. (Minette ores are not nearly so rich in iron as Swedish ores, but they contain less silicon and more calcium than the Salzgitter ores.) However, it soon turned out that the German Government did not intend to make full use of the Lorraine mines. The Nazis cut down the ore and coal supply of the French furnaces, and refused to release French soldiers who were coal miners. Even in Belgium, where the local coal supply is much more plentiful, blast furnaces have been cut down to 40% of their pre-invasion output. The only explanation is that the vested interests of the Hermann Goering Works in the exploitation of the Salzgitter ores were a powerful barrier against a more reasonable economic policy. Certain indications in recent months may mean that this policy is being revised.

(Continued on page 116)

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NAZI STEEL

(Starts on page 108)

Germany, including Austria and Sudetenland, produced 25,300,000 tons of steel annually immediately before the outbreak of war, and the output was apparently still on the increase up to the summer of 1940, new plant having come into operation. Later, however, according to all the major company reports, German steel production could only be just maintained at the mid-1940 level. Of the non-German countries inside the Axis realm, only Italy seems to have increased her steel production to a small extent, mainly by the large-scale use of electric furnaces. The supply of Swedish ores is probably not a major difficulty, though a large-scale increase to replace German ores would probably not now be feasible. Transport of ores, after the severance of the Narvik route, is only possible during the summer months, and then under convoy to protect the ships from Russian submarines. New harbor facilities are being constructed in Lulea, Sweden, to replace the destroyed docks at Narvik.

Meanwhile, the supply of coal, which was formerly considered to be comparatively secure, has developed into a main bottleneck. The output per man-shift has decreased since 1938, and in spite of the employment of very large numbers of foreign workers (the German press speaks of hundreds of thousands), in spite also of a vigorous fight against absenteeism and slackness, and in spite of a thorough administrative reorganization, the total output has not been raised in Germany, while it has been severely cut in some coal mining districts in the occupied countries.

The necessity for sending enormous supplies to the Russian front and the building of fortifications along the invasion coast have strained the transportation system severely. It is not even possible to return any large quantities of iron scrap from the battle fronts. It has now become increasingly difficult to overcome the raw material shortages by civilian restrictions, for production is concentrated in as few factories as possible and the number of types has been greatly reduced. Just a few examples have been taken at random from the German press: There are now manufactured in Germany only six patterns of pocket knives, six varieties of scythes, two varieties of ploughs and of threshing machines, one type of barbed wire for non-military use. Numerous varieties of consumer goods cannot be produced at all.

To replace the many overlapping bureaucratic controls, a new compulsory organization known as the "Reich Association for

(Continued on page 118)

NAZI STEEL

(Starts on page 108)

Iron" was instituted in June 1942. It is, in fact, a huge vertical cartel, which combines all productive, trading, and research companies of the iron industry, including both rolling mills and ore mines. Efforts are being made to extend the use of heat treated strong steels. Half the weight of many needed metal parts could be saved, but the technique calls for a "revolutionary change in the whole outlook of German engineers".

The most striking recent development, however, has been the giant scrap campaign. There have been scrap collections in Germany before, but none on a comparable scale. All industrial establishments and all large and medium sized farms were required to give up all their old iron, their unprocessed iron and steel material of unusual types and sizes, any semi-finished iron and steel products, and material for canceled orders.

Furthermore, all spare parts and any machinery not needed at present were requisitioned; under certain conditions plants were shut down. No considerations of post-war economy were allowed to interfere. The really significant aspect of the campaign is that, according to German press reports, several million tons of semi-finished products were collected, and that huge quantities of brand-new machinery were to be seen in the collection centers. The delivery was voluntary in name, but was "supported" by S.S. authorities. As a rule, the industrialists and farmers received only the scrap price for the metal.

The reasons for this large-scale scrapping of German industrial installations have been fairly frankly stated in German newspapers. The most vital consideration is that about half the coke is saved by using scrap instead of ore. Secondly, this saving of coke (and ore) results in an appreciable transport economy, in spite of the need to transport the scrap to the furnaces.

In spite of various more optimistic predictions by Englishmen, there is no conclusive evidence that the production of high grade steel will ever be prevented in Germany through the lack of alloys. Russia furnished Germany with ample manganese up to the invasion date (June 1940) and now the Germans have captured the important manganese mines near Stalingrad. The stocks of alloy metals in Germany must have been considerable at the outbreak of war, and certain additional quantities may have been transported from the Far East until Russia entered the war. Much research has also been expended on the improvement of steel alloys.

IRON POWDER

(Continued from page 64)

price of 2¢ per lb. It has its uses, but the manufacturer cannot guarantee results generally expected of compressed and sintered parts. The price scale goes up to $1.00 per lb. and even higher for small quantities. Between these prices (2¢ to $1.00 per lb.) material is available, but the price to be paid naturally depends upon the chemical specification of the iron powder itself, the facility with which it is worked and the physical characteristics of the finished part to be made therefrom.

In reviewing the five groups the reader can readily see that there is merit in each type of iron powder. Since there is a market for high priced powder and for low, it would appear that the *price* of iron powder is not the fundamental governing factor. The purer the iron and the lower its relative cost, the larger the prospective outlet. It has been indicated by one user that the price of the raw material does not affect him very much, for it is the chemical and physical characteristics that allow him to produce desirable parts. His labor cost is 90% of the production and the raw material but 10%. In such a case the raw material could cost twice as much and the final product would not cost much more.

Non-Metallurgical Uses

Those acquainted with the art of powder metallurgy realize that there are a great many uses for iron powder and that each application requires its own most appropriate type. There are two other very large consuming industries, but as they do not come under the heading of powder metallurgy they will merely be mentioned.

The dye-stuff industry uses iron powder, particularly for deoxidation, in the manufacture of aniline. The quantities used for this purpose are quite appreciable.

The other large consumer not under the classification of powder metallurgy is in the field of agriculture. A healthy wheat grain has a smooth skin, an unhealthy one a crinkly skin. Both here and abroad it is a practice to place mixed grain and iron powder in a tumbling equipment, wherein the very finely divided iron settles only in the grooves of the unhealthy grains, which are then eliminated by passing them under a magnet, leaving only the sound grains for milling.

We have not been able to check the exact quantity used in these two fields, but are assured that the amount of iron powder runs into many hundred tons yearly.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Kennametal tools, specifications and prices. McKenna Metals Co. Bulletin Hf-238.

140-page working manual on "Cylindrical Superfinishing." International Machine Tool Corp., Foster Div. Bulletin Hf-410.

Forging presses. Ajax Mfg. Co. Bulletin Ff-105.

Horizontal extrusion presses, rolling mills, pumps and accumulators. Hydropress, Inc. Bulletin Ff-394.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin Ff-132.

Cutting Oils. Cities Service Oil Co. Bulletin Ec-113.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin Ke-118.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin Af-335.

36-page booklet on properties and uses of cutting oils. Gulf Oil Corp. Bulletin Ef-360.

Guide book shows forty different ways to cut machining costs. Continental Machines, Inc. Bulletin Ef-170.

A new and attractively illustrated catalog describes the mounted wheels, Handee and Hi-Power tools and a wide variety of accessories developed by Chicago Wheel & Mfg. Co. Bulletin Kf-230.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin Kf-433.

Convenient, pictorial chart shows abrasive cloth gadgets in a form that will guide users in the proper finishing operation. Behr-Manning Corp. Bulletin Nf-467.

New leaflet shows "dag" colloidal graphite as a lubricant for running-in internal combustion engines, compressors and other mechanical equipment. Acheson Colloids Corp. Bulletin Lf-465.

"Hyper-milling", a radical innovation in face-milling of steel, is described in booklet by Firth-Sterling Steel Co. Bulletin Lf-177.

Abrasive belt polishing machines. Divine Brothers Co. Bulletin Kf-434.

Metal cuttings saws. Wells Mfg. Co. Bulletin Kf-316.

Cutting oils. Warren Refining & Chemical Co. Bulletin Kf-454.

New 32-page book presents details, photographs and tables on operation of abrasive cutting machines. Andrew C. Campbell Div., American Chain & Cable Co. Bulletin Nf-466.

Newly developed equipment incorporating use of surface coated abrasive belts for producing faster finishes is described in booklet issued by Minnesota Mining & Mfg. Co. Bulletin Ag-470.

FERROUS METALS

Enduro stainless steels. Republic Steel Corp. Bulletin Hf-8a.

Steel Stock List. Jos. T. Ryerson & Son, Inc. Bulletin Fe-106.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin Kd-85.

Free Machining Steels. Monarch Steel Co. Bulletin Cd-255.

Tool Steels. Bethlehem Steel Co. Bulletin Ce-76.

Die Steels. Latrobe Electric Steel Co. Bulletin Ld-208.

Steel data. Vanadium-Alloys Steel Co. Bulletin Kd-294.

Enameling iron sheets. Inland Steel Co. Bulletin Ld-295.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin Kd-229.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin Hb-4.

Simplified method for calculating heat treatment of alloy steels. Peter A. Frasse & Co., Inc. Bulletin Cf-172.

Four Coppco tool steels. Copperweld Steel Co. Bulletin Cf-311.

Nitralloy and the Nitriding Process. Nitralloy Corp. Bulletin Df-116.

Information for determining overall heat transfer rates. International Nickel Co. Bulletin Kf-45.

Wall Chart on spark testing tool steels. Carpenter Steel Co. Bulletin Kf-12.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin Kf-429.

Steels. Boker & Co. Bulletin Kf-450.

Cold drawn steels. Wyckoff Drawn Steel Co. Bulletin Kf-99.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin Ox-74.

Saving of stainless steel through use of Pluramelt. Allegheny Ludlum Steel Corp. Bulletin Df-92.

New 60-page data book on molybdenum wrought steels has been issued by Molybdenum Corp. of America. Bulletin Nf-312.

Use Handy Coupon Below
for Ordering Helpful Literature.
Other Manufacturers' Literature
Listed on Pages 132, 134, 136, 138, 142,
144 and 147.

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Check or circle the numbers referring to literature described on these 8 pages.

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Ff-105	Kf-316	Cf-172
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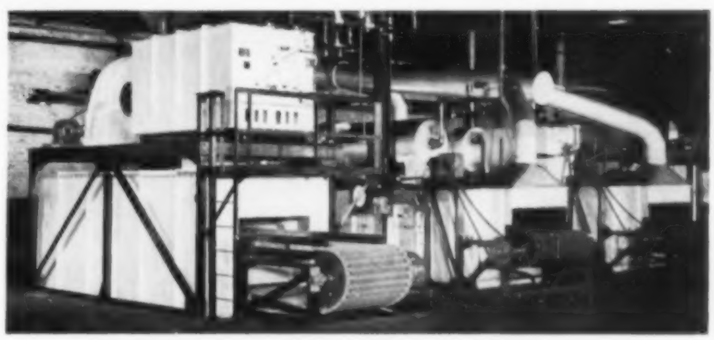

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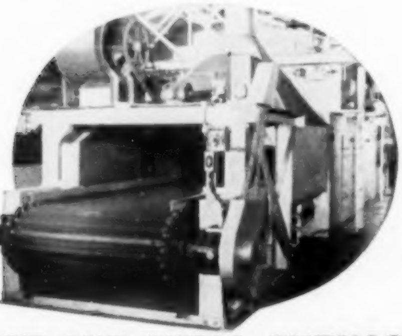

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Hyatt Roller Bearing Co.
Page Steel & Wire Co.
Pittsburgh Tool Steel Wire Co.
Steel Co. of Canada
Thompson Products Co.
Timken Roller Bearing Co.
Wickwire-Spencer Co.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New leaflet describes Jessop Steel Co.'s Truform die steels. Bulletin Nf-173.

Shop notes on the machining of stainless steels are presented in new 24-page book by Rustless Iron & Steel Corp. Bulletin Nf-169.

Facts and figures for the practical use of NE steels are presented in booklet by Joseph T. Ryerson & Son, Inc. Bulletin Ag-106.

NON-FERROUS METALS

Silver alloy brazing. Handy & Harman. Bulletin Hf-126.

Bronze. Frontier Bronze Corp. Bulletin Kf-455.

Various applications of bronze in the war industries are shown in new 8-page booklet by Ampco Metal, Inc. Bulletin Lf-175.

Copper Alloys. American Brass Co. Bulletin Kd-89.

Aluminum alloys for aircraft. Reynolds Metals Co. Bulletin Lf-436.

October Copper & Brass Research Assn. "Bulletin" features article on radio's use of brass. Bulletin Lf-382.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin Af-337.

New edition of "Machining Alcoa Aluminum". Aluminum Co. of America. Bulletin Kf-54.

New, complete catalog describes features and savings incorporated in die casting equipment of Lester-Phoenix, Inc. Bulletin Kf-437.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin De-307.

Dowmetal data book. Dow Chemical Co. Bulletin Ec-215.

Handy, compact reference data on brass and bronze castings. Hammond Brass Works. Bulletin Df-371.

Reference on properties of lead. St. Joseph Lead Co. Bulletin If-415.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

New "Copper Guide" is a handbook for easy reference to technology and properties of copper and copper base alloys, welding technique, etc. Revere Copper and Brass, Inc. Bulletin Nf-239.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin Nf-163.

WELDING

Arc Welding. Lincoln Electric Co. Bulletin Ff-10.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

New chart explains how to select proper flux for every welding, brazing and soldering job, gives answers to 400 metal-joining questions. Krembs & Co. Bulletin Ff-393.

Electrode quantity and welding time graph. Arcos Corp. Bulletin Ld-191.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin Ge-63.

"Fight-waste" booklet. Air Reduction Sales Co. Bulletin If-69.

Shield Arc electrodes. McKay Co. Bulletin Gf-248.

A-C welders for use with Unionmelt process. Westinghouse Electric & Mfg. Co. Bulletin Kf-134.

Sciaky radial portable welder. Sciaky Brothers. Bulletin Kf-425.

Castolin Eutectic Alloys as a substitute for scarce bronze or brass welding rods. Eutectic Welding Alloys Co. Bulletin Lf-301.

Two-stage "Regolator" for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

New catalog contains 88 pictures of new Suttonizing welding method for reclamation of high speed steel tools. Welding Equipment and Supply Co. Bulletin Lf-464.

Arc welding accessories available through General Electric Co. are illustrated in new Bulletin Lf-60.

New precision welder with the streamlined arc is described in leaflet issued by Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

Preheating, welding and normalizing by electrical reaction and induction is described in leaflet by Electric Arc, Inc. Bulletin Ag-468.

Arc-welding without preheat in the repair of brass and bronze castings is described in engineering data sheet issued by Ampco Metal, Inc. Bulletin Ag-175.

Speed is increased 20 to 30% and power costs cut one-third with the Flexarc A-C welders described in new booklet by Westinghouse Electric & Mfg. Co. Bulletin Ag-134.

"Sureweld" protected arc electrodes, in many types and sizes, described in illustrated literature. Hollup Corp., division of National Cylinder Gas Co. Bulletin Ag-331.

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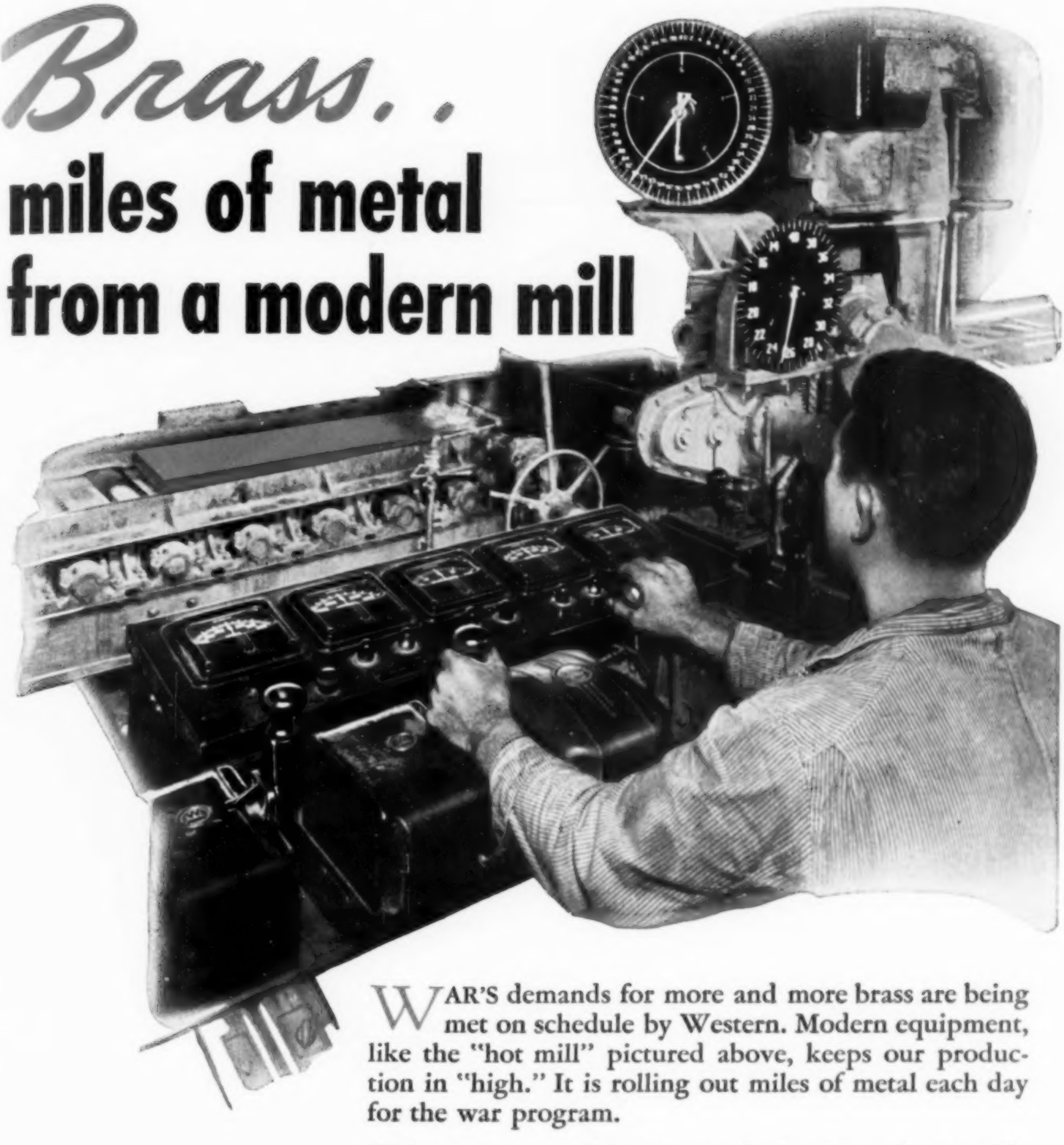

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

TESTING & CONTROL

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin If-401.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

Metallurgical laboratory apparatus. Burrell Technical Supply Co. Bulletin Ff-213.

Tension and compression strains. American Instrument Co. Bulletin Nv-259.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin Hc-6.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin Bf-345.

Modern Polishing. Tracy C. Jarrett. Bulletin De-303.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

Optical Aids. Bausch & Lomb Optical Co. Bulletin Ce-35.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin Hb-180.

Universal enclosed terminal head. Arklay S. Richards Co. Bulletin Ne-330.

Metallographic polishing powder. Conrad Wolff. Bulletin Cf-368.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin Df-377.

8-page leaflet makes a detailed presentation of the Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

Revised catalog of Micromax thermocouple pyrometers has just been issued by Leeds & Northrup Co. Bulletin Lf-46.

Laboratory and industrial electric furnaces manufactured by Cooley Electric Mfg. Corp. are described in new Bulletin Lf-462.

Automatic stress-strain recording is discussed comprehensively and equipment is pictured in new booklet by Baldwin-Southwark Div., Baldwin Locomotive Works. Bulletin Lf-67.

New bulletin interprets WPB conservation order L-134 as it applies to use of thermocouples and thermocouple protecting tubes for pyrometric instruments. Wheelco Instruments Co. Bulletin Lf-110.

Metallurgical Equipment. Adolph I. Buehler. Bulletin Ke-135.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

Potentiometer temperature indicators. Foxboro Co. Bulletin Ef-21.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin Kf-206.

Pyrovac radiation pyrometer. Bristol Co. Bulletin Kf-87.

Complete information on National Spark Testing Assn.'s methods of ascertaining the chemical composition of steel. Bulletin Kf-428.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

Surface Analyzer. Brush Development Company. Bulletin Kd-288.

Polishing Machine. Cincinnati Electrical Tool Co. Bulletin Ox-97.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin Kc-37.

X-Ray metallurgical laboratory service is described and illustrated in new file folder issued by Claud S. Gordon Co. Bulletin Nf-53.

64-page booklet on the precision control of industrial processes has been issued by Brown Instrument Co. Bulletin Nf-3.

Constant temperature dry-ice cabinet for temperatures from minus 90 deg. to 220 deg. F. is new laboratory instrument described in leaflet by American Instrument Co. Bulletin Ag-259.

Dillon tensile tester and the Dillon dynamometer are described and illustrated in new leaflet issued by W. C. Dillon & Co. Bulletin Ag-466.

HEATING • HEAT TREATMENT

Tempering, annealing, stress-relieving. Leeds & Northrup Co. Bulletin Hf-46.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

Industrial furnaces for ingots, billets, slabs, bars, rods and gun barrels. Wellman Engineering Co. Bulletin If-419.

New 8-page booklet describes and illustrates gas, oil and electric heat treating and carburizing furnaces of Holcroft & Co. Bulletin Lf-203.

Faster production with Tocco hardening, brazing, annealing and heating machines is set forth in new 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

Kleen-well oil strainers for quench oil cooling systems is described in leaflet by Bell & Gossett Co. Bulletin Lf-287.

Gas cracking unit for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels is described by Hevi-Duty Electric Co. in new Bulletin Lf-44.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Liquid salt baths for carburizing, annealing, reheating, tempering and neutral hardening are described by E. F. Houghton & Co. in new Bulletin Lf-38.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel are described by United Chromium, Inc., in new Bulletin Lf-463.

Annealing and stress-relieving of cartridge cases are discussed by Surface Combustion Corp. in new Bulletin Lf-51.

Method of handling cylinder anhydrous ammonia for metal treaters is comprehensively described and pictured in 12-page booklet by Armour Ammonia Works, division of Armour and Co. Bulletin Lf-443.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin Ff-286.

Heat treating furnaces. Johnston Mfg. Co. Bulletin Ff-155.

Heat treating production. Lindberg Engineering Co. Bulletin Bf-66.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin Ce-302.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

Modern electric furnaces for heat treating are described by Harold E. Trent Co. in new Bulletin Lf-461.

Low pressure oil burners. North American Mfg. Co. Bulletin Na-138.

Industrial Furnaces. W. S. Rockwell Co. Bulletin Kc-34.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin Nc-15.

Modern Shell Furnaces. Mahr Manufacturing Co. Bulletin Bf-5.

Butterfly Valves. R-S Products Corp. Bulletin Bf-234.

Gas-fired Forge Furnaces. Eclipse Fuel Engineering Co. Bulletin Af-226.

Vertical Furnace. Sentry Co. Bulletin Ne-114.

Conveyor Furnaces. Electric Furnace Co. Bulletin Be-30.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin Ce-219.

Condensed Catalog. American Gas Furnace Co. Bulletin Ff-11.

Convected Air Furnace. Despatch Oven Co. Bulletin Nd-123.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

Heat treatment in electric salt bath furnaces. Ajax Electric Co., Inc. Bulletin If-43.

New Electric Furnace. American Electric Furnace Co. Bulletin Gd-2.

Furnace Experience. Flinn & Dreffein Co. Bulletin Bc-82.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin Bb-187.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin Ke-260.

High Temperature Fans. Michiana Products Corp. Bulletin Hb-81.

Turbo-compressors. Spencer Turbine Co. Bulletin Cf-70.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Drycolene. General Electric furnace atmosphere. Bulletin Df-60.

Electric Furnaces for laboratory and production heat treatment. Hoskins Manufacturing Co. Bulletin Cf-24.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

Electric box type and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

Dual-Action quenching oil. Gulf Oil Co. Bulletin Df-360.

Induction heating. Induction Heating Corp. Bulletin Ef-323.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin Ef-386.

Sub-zero equipment for aluminum storage, shrinking of metal parts. Kold-Hold Mfg. Co. Bulletin Kf-399.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

Heat treating furnaces. McCann Furnace Co. Bulletin Kf-446.

Furnaces. Tate-Jones Co. Bulletin Kf-447.

Gas-burning equipment. National Machine Works. Bulletin Fe-310.

Furnaces. Vulcan Corp. Bulletin Kf-448.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin He-41.

New Heat Source, for Heat Treating, Brazing and Melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin Kc-211.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

Flame-type mouth and taper annealing machine for steel cartridge cases is described in new leaflet by Morrison Engineering Corp. Bulletin Nf-305.

No-Carb, a liquid paint for prevention of carburization or decarburization, is described and use illustrated in new leaflet by Park Chemical Co. Bulletin Nf-141.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin Ag-448.

Attractive 16-page illustrated catalog describes furnaces for heat treating ferrous and non-ferrous metals. Despatch Oven Co. Bulletin Ag-123.

War production with standard rated heat treating furnaces is pictured in new bulletin by Surface Combustion. Bulletin Ag-51.

New manual shows many new technical advances — features exclusive, easy-selection charts on gas-burning equipment. National Machine Works. Bulletin Ag-310.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin Ce-75.

Heavy Duty Refractories. Norton Co. Bulletin Ie-88.

Super Refractories catalog. Carborundum Co. Bulletin Ld-57.

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin Ef-218.

Conductivity and heat transfer charts. Johns-Manville. Bulletin Df-100.

Savings in construction time, labor and money with use of the all Ramix bottom for basic open hearth furnaces are shown in new leaflet by Basic Refractories, Inc. Bulletin Nf-192.

Brickseal refractory coating and discussion of why furnace walls break down are presented by Brickseal Refractory Co. Bulletin Ag-469.

FINISHING, PLATING, CLEANING

Technical and engineering data on Tygon and typical uses, such as tank linings, are presented by United States Stoneware Co. in new Bulletin Lf-356.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment are attractively described in new 24-page catalog by Detroit Rex Products Co. Bulletin Lf-111.

Cleaning Manual. Oakite Products, Inc. Bulletin Hf-296.

Airless Rotoblast. Pangborn Corp. Bulletin Hf-68.

A protective, deep black finish to steel. Heatbath Corp. Bulletin Hf-189.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin Ne-329.

112-page manual "Chemicals by Glyco". Glyco Products Co., Inc. Bulletin Ff-397.

Pickling. Wm. M. Parkin Co. Bulletin Ff-193.

Modern Pickling. The Enthone Co. Bulletin Ff-240.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin Hd-29.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin Bf-352.

"Indium and Indium Plating". Indium Corp. of America. Bulletin Df-376.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Casting cleaning methods in foundries. N. Ransohoff, Inc. Bulletin Ef-381.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin Gf-256.

Rust Preventative. Alox Corp. Bulletin Nb-212.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin Ge-143.

Comprehensive new booklet describes the rust inhibiting wax coatings for protection of metal against rust and corrosion developed by S. C. Johnson & Son, Inc. Bulletin Kf-426.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin Kf-456.

Anodizing and plating equipment. Lasalco, Inc. Bulletin Kf-457.

Degreasers. Phillips Manufacturing Co. Bulletin Nc-254.

MELTING • CASTING • MILL OPERATIONS

Care of crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin Ff-396.

Rotary positive blower installations in several fields, including smelting, steel mill and foundry. Roots-Connersville Blower Corp. Bulletin Hf-131.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin Bf-16.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.

Ingot Production. Gathmann Engineering Co. Bulletin Ka-13.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin Bf-124.

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin Bf-357.

Fisher Furnace Co.'s stationary and tilting type crucible melting furnaces for ferrous and non-ferrous metals. Bulletin Af-195.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin Ga-90.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin Hd-271.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin Kf-451.

Interesting, illustrated bulletin describes foundry practice for manganese-bronze. Niagara Falls Smelting & Refining Corp. Bulletin Ag-467.

ENGINEERING • APPLICATIONS • PARTS

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin Kf-430.

Carburizing Boxes. Pressed Steel Co. Bulletin Ce-269.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin Bf-233.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin Ld-32.

Meehanite Castings. Meehanite Research Institute. Bulletin Bf-165.

Ledaloyl, self-lubricating bearings. Johnson Bronze Co. Bulletin Af-237.

Metal Baskets. W. S. Tyler Co. Bulletin Bf-359.

Steel Castings. Chicago Steel Foundry Co. Bulletin He-184.

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Heat Resisting Alloys. General Alloys Co. Bulletin D-17.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin Bb-84.

Metal Powders. Metals Disintegrating Co. Bulletin Ec-208a.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin Cf-370.

Handy wire data chart. Callite Tungsten Corp. Bulletin Ef-327.

Corrosion and heat resistant alloy. Lebanon Steel Foundry. Bulletin Ef-387.

Lead-base metals. Magnolia Metal Co. Bulletin Kf-422.

Comprehensive, pictorial description of wide range of applications where Velvetouch Bimetallic friction material may be installed is described in new plastic-bound booklet by the S. K. Wellman Co. Bulletin Kf-423.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin La-23.

Duriron. A new bulletin on steam jets, ejectors, tank outlets and spray nozzles. Duriron Co. Bulletin Gc-152.

Heat and corrosion-resisting castings. Standard Alloys Co., Inc. Bulletin Ke-151.

Centrifugal Iron. Shenango-Penn Mold Co. Bulletin Ka-174.

Industrial baskets, crates, trays and fixtures are described by Rolock, Inc., in new Bulletin Lf-299.

Standard and special shapes of seamless steel tubing are described and pictured in new leaflet by Summerill Tubing Co. Bulletin Lf-108.

New 12-page booklet describes background, manufacture and typical applications of Tungsten. Cleveland Tungsten, Inc. Bulletin Lf-460.

Handling baskets for heat treating, washing, dipping, degreasing, etc., are shown in new leaflets issued by Union Steel Products Co. Bulletin Lf-459.

Instrument Specialties Co. has issued "Better Brush Springs", reference leaflet showing how "Microprocessed" beryllium copper brush springs have answered demands and includes data and formulae for spring design. Bulletin Nf-468.

Conversion from several types of scarce metals to malleable iron is described and illustrated in new booklet by Lake City Malleable Co. Bulletin Nf-469.

Cooper standard alloys, its services and facilities are described in new bulletin. Cooper Alloy Foundry Co. Bulletin Ag-144.

Seamless pressed steel heat treating containers. Eclipse Fuel Engineering Co. Bulletin Ag-226.

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CRITICAL POINTS

BY THE EDITOR

RETURNING east from Colorado, stopped off at Moline-Rock Island-Davenport, interrupted busy men like HY BORNSTEIN, GORDON WILLIAMS, JOHN GRAHAM and PAUL CUNNICK, and discussed absorbing topics like the hardening of armor piercing shot and shell, and the casting, heat treatment and welding of armor plate, for the Army's medium tank was developed at Rock Island Arsenal, and Tri-Cities (in peacetime the center for agricultural implements) is now engaged in making better tanks and still better tank busters. Regretful that any revealing news about these matters will not pass the censor, but proud that ASMembers who excel in the arts of peace are able to turn to their fundamental metallurgical knowledge and devise methods whereby superior war materials are made in mass production by methods quite bizarre as compared with the ordnance practices of the last war....One publishable item from BORNSTEIN and WILLIAMS of Deere & Co. is interesting. It concerns the specification requirement that a certain item be withdrawn from the quench and put into the tempering furnace before its average temperature drops below 300° F. How measure this heat, when the surface is considerably cooler and the center considerably hotter than the average? Use a calorimeter. (The books say that the scientific armorer of the Spanish war era estimated temperatures by taking a copper ball from the furnace, quenching it in a bucket of water and measuring the temperature rise.)....PAUL CUNNICK, now Major of Ordnance, took quiet satisfaction in exhibiting the model forging and heat treating building at Rock Island Arsenal which contains the widest range of equipment, both in size and function, that this observer has ever found under one roof, but everything ship-shape — especially the furnaces which were spick and span and apparently in perfect condition. New annealing, hardening, tempering and nitriding furnaces are being installed in this whole manufacturing region in great number, as would be anticipated from the change in product; implements depend largely on cast iron, ordnance on alloy steel....Controlled atmospheres are also commonplace in regions where fast annealing cycles for malleable cast iron are the rule rather than the exception. Unusually clean surfaces on hardened steel are had by "dry cyaniding" (introducing a little ammonia into the gas carburizing furnace); surfaces are file hard on slow cooling, and so warpage during the quench is avoided. Carriers and trays that do go through an oil quench with the work are likely to drag out enough oil on their surface to upset the atmosphere on their next trip. Consequently the carriers go under a hood where the oil is burned off by gas flames....JOHN GRAHAM of International Harvester's Farmall Works demonstrated how recent substitutions not only saved a lot of nickel, but the necessary revision in heat treating schedule turned out to be considerably cheaper: The part is a splined shaft, about 1½ in. diameter by 10 in. long, on the end of which is a 3-in. bevel gear. Gear teeth must be scleroscope 75 to 85 hard; shaft 45 to 55. The old practice used S.A.E. 3115 (0.50 Mn, 1.25 Ni, 0.65 Cr), carburized, hardened, drawn completely to scleroscope 45 to 55, and the gear end hardened in lead from 1525° F. The first substitution was to S.A.E. 4120 (0.80 Mn, 0.70 Cr, 0.25 Mo), but to get good core structure this must be hardened from a 125° higher heat — too hot to operate a lead bath successfully. It therefore was gas carburized, quenched direct from 1650° F., stress relieved to give the gear the correct properties, and only the shaft end drawn in lead at 1300° F. (time 3 min.). The gear is cooled in water, the shaft in air. This new schedule is followed with the NE steels that have even more recently been substituted for the substitute.

Plowshares to Swords

Saves, Both on Alloys and Heat Treatment

AMAZED to hear BEN HOPKINS, head of Cleveland Graphite Bronze, say that the silver used every day in electroplated surfaces for heavy duty bearings in a new factory now getting into production would be measured in tons, and while a ton of metal is not very much in a bridge girder, it is a whale of a lot in an electroplate, even a thick one. Mused also on the fact that good bearings can be made of so many different things and lubricated with so many materials, but thought that, after all,

such was a necessary condition for the prehistoric invention of the wheel. That early step upward from barbarism could have been taken only because almost anything would do for a sort of a bearing. Doubtless almost everything *was* used, and the early artificers soon found that what we know as bronze — the first alloy used for tools and weapons — was best of all, a "fact" still found in many 20th century textbooks and handbooks which has caused no end of trouble between metallurgists and mere engineers and designers. The bearing alloy invented by Mr. BABBITT was comparatively recent, and when metal came to be examined under a microscope it was necessary to explain why its complex structure of tiny hard crystals in a softer "cement" should make such a good bearing. The dictum that such *must* be the structure of a good bearing material seems shattered by the recent bearings using various kinds of electroplates, the intriguing possibilities of aluminum bearings, and the statement of CARL SWARTZ, metallurgist of Cleveland Graphite Bronze, that lead is the bearing metal par excellence....One would be hard put even to define the word "bearing" so as to denote its engineering meaning, but this is perhaps only another example of the truism that we know the least (scientifically and accurately) about the things we have used the longest.

Thoughts on Bearings — New & Old

DID you know that gray iron cupolas, on the average, consume at least 20% more coke than necessary? At least this is the opinion of International Nickel's DONALD REESE, now on loan to War Production Board, who spoke as a government official concerned with the conservation of fuel, and 20% of 2,000,000 tons of foundry coke is quite a pile. Likewise, foundries tend to waste steel scrap, generally using 50% more than necessary to attain the desired chemistry in their castings. Speaking as a metallurgist, he outlined four steps to take in order to save fuel without damaging the iron: First, exercise metallurgical control of carbon as well as silicon in the iron; if carbon is controlled, silicon control usually takes care of itself. Second, *size* the coke so that its largest dimension is 1/12 the cupola diameter. Third, *weigh* the coke charges — perhaps a revolutionary step, for many foundries do not even weigh the iron! (Measured weight is much more accurate than guessed-at volume, or so many forkfuls; even rain-soaked coke is less than 5% heavier than dry.) Fourth, use *small* charges. A coke layer 4 in. thick is a good figure to shoot at. This means about 7½ lb. of coke per sq.ft. of cupola area, or a 100-lb. coke charge for a 48-in. cupola. Compare this with the customary 200 to 250 lb.! As a matter of fact, REESE has records of operating cupolas carrying coke-charges that range from as little as 5 to as much as 30 lb. per sq.ft. of area, but the foundries with the best fuel economy are those which use the weight of coke charge as a reliable yardstick for melting performance.

Better Cupola Practice Saves Coke & Scrap

COMMENTING on the fact that the metallurgist is a rarity who has properly sold himself to the management and who can't be talked down by the production engineer or the purchasing agent, ERNEST HERGENROETHER is fond of telling a story of Mack, a Detroiter who achieved the goal: His big boss came to him one day and said, "Mack, you know I grow hogs out on my farm, but the hams get a green mold and I can't keep it off." Mack was a farm boy and he knew instantly what was the trouble, but he was also a wise bird, so he said, "I'll check into it; it's probably a serious problem. Bring me in one of the hams and we'll do some laboratory work and see what is the matter." So the boss brought in a ham (which shortly reappeared on Mack's dining-room table) but Mack didn't go near the boss. So in about a week the boss called him up and said, "What are you doing about the hams?" and Mack said, "I've given it some personal attention and I think I have about got the answer." So a week later he went into the front office and told him what to do, and the boss did it, and the green mold disappeared. So the big boss, to the day he died, swore that Mack was the best —— —— metallurgist in the country, all on account of fixing those hams, which any farm boy from the corn belt could have done.

How to Be a Prominent Metallurgist

METALLURGICAL note from "See Here, Private Hargrove": "A new rank among the noncommissioned officers, announced the grapevine comic page, is the rank of metal sergeant. The rank is conferred only by the men in the ranks, and a metal sergeant is distinguished by 'the silver in his hair, the gold in his teeth, and the lead in his pants'." If this appeals to you as being funny, by all means rush out and buy a copy of this best-seller....*P.S.* The above book review is something less than fair, for the very next chapter is adult, climactic, and humorous.

REGRET to have to announce that this is the last issue of METAL PROGRESS to appear in *de luxe* page size. Governmental orders have restricted the use of print paper and engraver's metal, and for the duration this magazine will reduce the number of illustrations and adopt a page size leaving practically no margins (uniform with the other technical journals).

This is the first third of a notable paper read before the Detroit Chapter, ⚙, November 1942 meeting, on the general subject of "Fatigue of Metals as Influenced by Design and Internal Stresses". The author is head of the Mechanical Engineering Dept. 1 of G.M.'s Research Laboratories, and has had long experience in diagnosing service failures, and devising proper cures. Subsequent installments will describe some experiences with bolts, studs and gears, and finally the general problem of endurance under loads higher than the "true" fatigue limit will be expounded

PEENED SURFACES IMPROVE ENDURANCE OF MACHINE PARTS

BY J. O. ALMEN
Research Laboratories Division, General Motors Corp., Detroit

FULLY 90% of all fatigue failures occurring in service or during laboratory and road tests are traceable to design and production defects, and only the remaining 10% are primarily the responsibility of the metallurgist as defects in material, material specification or heat treatment. While this ratio is not a measure of the quality of workmanship contributed by each department, there can be no doubt that the metallurgist has a better appreciation of his responsibility for fatigue failures than has the designer, the engineer, or the man in the production department — in fact, it contributes to the relative irresponsibility of the engineer by over-willingness of the metallurgist to accept the blame when things go wrong.

Being metallurgists you are familiar with the routine followed when a broken part is received. The fracture is examined and is found to be due to fatigue, the material is analyzed for composition, sections are studied for all of the many things that are metallurgically important, and a report is written describing the things that are and are not up to par. But no matter how many possible metallurgical causes of trouble are found, such examination is far from sufficient unless the failure is also examined for design faults and bad fabrication and assembly practice. Most of the failed parts should not be sent to the metallurgist at all but, unfortunately, very few engineers or production men are adequately trained in diagnosing fatigue trouble, and failures are therefore seldom examined for contributing mechanical causes. Like the cowbird who lays her eggs in the nests of other birds, most of our engineers pass all fatigue problems on to the metallurgical department with the implication that something must be wrong with the material or with the heat treatment. The metallurgist does his metallurgical best and in the process frequently destroys the evidence of mechanical faults!

The study of fatigue of materials is properly the joint duty of the metallurgical, engineering and production departments. Unless all have an understanding of fatigue phenomena and the factors that promote fatigue, they cannot recognize their individual responsibilities. There is no definite line of demarcation between mechanical and metallurgical factors that contribute to fatigue and there must, therefore, be very close cooperation between the metallurgist and the engineering fatigue specialist, if such there is, or the metallurgist must possess the combined qualifications of metallurgist, designer and machinist. This overlapping of responsibility is not sufficiently understood in industry and hence the engineers are constantly demanding new metallurgical miracles instead of correcting their own faults. Until metallurgists insist on a competent examination for mechanical causes of fatigue failures, we cannot hope to make full use of our engineering materials.

Service Conditions Are Not Reproducible — The development of engineering materials, designs, and processes requires that we conduct laboratory

tests by which these factors may be evaluated, but to devise a reliable laboratory test is far from simple. The common belief that we can reproduce the conditions of service in a laboratory test is wholly erroneous. By the time the laboratory investigator has provided for all of the conditions that occur in service, he will, in the case of automobile parts, find himself on the road with a complete automobile, and even then he will not represent the type of driver who most severely taxes the strength of the machine.

Compromise Treatments — Many materials and processes have been graded and are still being graded by laboratory tests which are now known to have been very costly to the automobile industry (and to other industries as well). For example, the fiction that a carburized part should have a hard case to resist wear, and a tough core to resist breakage, arose from laboratory impact tests. In these tests the strength of the part was judged by the number or intensity of hammer blows it would withstand before fracture. Since gear teeth resisted impact fracture in accordance with the physical properties of the core, it seemed logical to specify heat treatments to bring out the best compromise between the imagined requirements of the case and the core. Being compromises, these heat treatments were not the best for either region.

If, instead of counting the number of impacts or measuring the intensity of hammer blows to produce fracture, the gear tooth had been examined after the first impact, the tooth would have been found bent and, therefore, ruined, and it would make no difference how many more blows were required to fracture the tooth.

This compromise heat treatment resulted in reducing the quality of many millions of gears before it was realized that gear teeth fail by fatigue and that fatigue failure, for the usual depth of carburization, always originates at the surface of the case. From this evidence it became clear that the heat treatment should consider the requirements of the carburized case only, and that the properties of the core were relatively unimportant, because, in bending and in torsion, the core serves mainly as a stuffing for the case.

Alloy Steels — Similarly, gear steels and steels for many other parts have long been selected by false standards that are based only upon arbitrary laboratory tests, among which are fatigue tests of ideal specimens. For many years industry has paid premium prices for alloy steels because of fancied advantages. Fatigue tests on actual machine parts, correlated with service records, have shown that there is no detectable difference between the high priced alloy steels and many of the low priced alloy steels when used in many machine elements. (This was demonstrated by A. L. Boegehold and the writer in a 1935 A.S.T.M. paper on rear axle gears.) Machine parts are so far removed from the ideal laboratory fatigue specimens that the latter are misleading as measures of worth. This is indicated by the relative slopes of the fatigue curves (as will be demonstrated later in this article) since the slopes of fatigue curves for machine parts under high loadings are always steeper than the slopes of fatigue curves for the preferred laboratory specimens by which materials are usually selected. In all probability there are real differences in the fatigue characteristics of the various alloys, but these differences are often so small in comparison with the mechanical fatigue hazards introduced by the design and fabrication of the machine part as to be negligible.

Fig. 1 — Transfer Print of Magnaflux Markings on Side of a Gear Tooth That Failed by Spalling, Undoubtedly Originating in Grinding Cracks

Mechanical Causes of Fatigue

It is possible to discuss only a few of the many mechanical causes of fatigue in the available space. The subjects selected are those which have not been given the attention they deserve in recent publications, or that may be somewhat differently interpreted. For a thorough and comprehensive review of fatigue literature, the recent book on "Prevention of the Failure of Metals Under Repeated Stress" by the staff of Battelle Memorial Institute is highly to be recommended.

Surface Finishes — Efforts to improve products by improving surface finish may sometimes have the opposite effect. Highly finished surfaces and fillets may lead to a false sense of security if, as the result of machining or straightening operations, the parts have high internal stresses of the wrong kind. In ground surfaces, such as shafts, wrist pins and gear teeth, the grinding operations may introduce high surface tension stresses and thus promote fatigue failures. More harm than good often results from the grinding of machine parts. The surface tension stresses from grinding are often so great as to produce visible or magnaflux surface cracks — but, whether detectable or not, surface tension due to finishing operations is frequently very serious.

For example, Fig. 1 is a magnaflux transfer print on transparent cellulose tape showing surface fractures in a ground gear tooth. This tooth

eventually failed by spalling which originated in these surface fractures. Since fatigue cracks start on the side of the gear tooth that is loaded in tension, the effective stress is the grinding pre-stress plus the working stress.

Frequently we find that a hardened part will show a file-soft skin after grinding, a surface which not only promotes fatigue but is also susceptible to seizure and galling.

Internal Stresses of the wrong kind are perhaps the most insidious of all fatigue hazards because we can seldom know their magnitude, or the pattern in which they are distributed within the material, or even whether they are alike for all commercially identical machine parts. Internal stresses may be the result of operating conditions such as occur in brake drums, clutch plates or other friction surfaces where the instantaneous temperature in a thin layer is so great that the surface layer is stressed by thermal expansion beyond its yield point in compression. When the source of heat is removed from such a part the heated surface layer is quenched by the adjacent cool metal and, under thermal contraction, it is so severely stressed in tension that fractures occur. This is, of course, the same thing that happens in grinding unless great care is used.

An estimate of the magnitude of the surface tension stresses set up by normal grinding practice was made in the following way:

A specimen of annealed spring stock 0.062 in. thick, 1 in. wide and 7 in. long was ground to a depth of cut of 0.002 in. After grinding the straight specimen was found to be curved concave on the ground side, indicating tension stress therein. Very thin layers were then removed from the ground surface by hand honing until the specimen regained its initial straightness. Measurements of the change in curvature with each thin layer removed permitted the stress distribution to be calculated, as follows:

Distance From Surface	Tension Stress
0.00005 in.	270,000 psi.
0.00013	110,000
0.00025	57,500
0.00035	37,500
0.00045	27,500

Obviously a stress of 270,000 psi., a stress just below the fracture point of full hard steel, could not be supported by the steel in the annealed state, from which it follows that the stressed layer was hardened by the heat of grinding to not less than Rockwell C-55. The extreme thinness of the hardened layer presents an interesting problem in hardness measurement, the unground and ground surfaces testing as follows:

	Unground	Ground
Rockwell B scale	88	89
Rockwell C scale	5	5
Vickers Brinell	193	199

These figures demonstrate the futility of our normal hardness measuring technique for measuring the hardness of the most significant portion of our machine parts, namely, the surface layer.

Residual Stresses From Processing — Internal stresses often result from the cooling of castings and forgings, or from the vigorous heat transfer of heat treating. Many parts, such as crankshafts, axle shafts, and camshafts require straightening, and since this is usually done at room temperature and the part rarely stress relieved after straightening, the result is severe internal stresses. In turning, milling and other machining operations, it is necessary that metal be removed at a minimum cost and therefore the cutting tools often take deep cuts at high feed rates. Since metal cutting is more accurately described as a metal tearing operation so far as stresses are concerned, we need not be surprised to find serious internal stresses to considerable depths after machining. When metal cutting has been unusually severe or after operations such as punching and shearing, we often find that the surfaces are actually fractured. Finish machining or grinding rarely goes deep enough to remove the internally stressed metal from previous rough machining — and these operations add stresses of their own.

Whenever it is economically practicable,

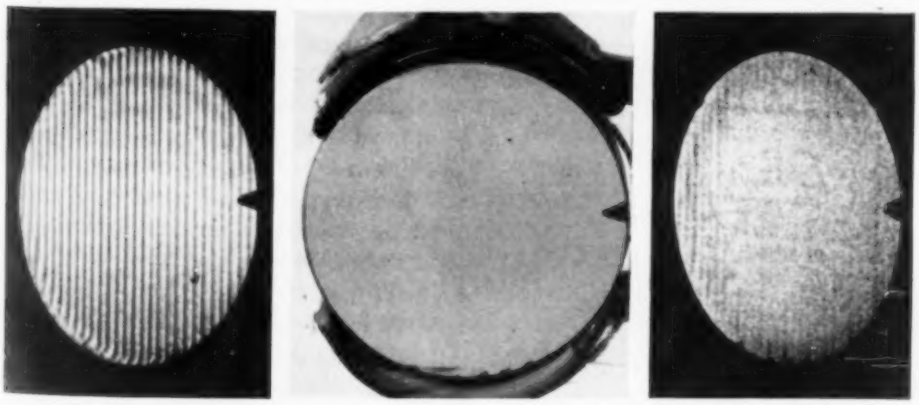


Fig. 2 — Views Showing Deep Seated Disturbance by Rough Machining. Left: Bar end after rough machining on shaper. Center: Same after carburizing, grinding smooth and lapping — all in a direction perpendicular to machining. Right — Shot-blasted surface shows traces of both the machining and the grinding marks

internal stresses that produce tension in any surface layer subjected to cyclic tension stress should be reduced or removed — or, better still, converted to compressive stress by suitable treatment, for all fatigue failures are due to *tension* stresses.

The layer of metal "injured" by machining is undoubtedly deeper than is generally believed, nor does it "recover" after heating for long periods at high temperatures. For example, the left view in Fig. 2 on page 211 shows a bar of 4615 steel after rough machining on a shaper. This piece was then carburized for 8 hr. at 1700° F., cooled in the box, reheated to 1500° F., quenched in oil and drawn at 300° F. for 1 hr. The machined surface was then ground in a direction at right angles to the shaper marks to a depth of 0.0055 in. below the last visible tool mark. It was then polished and lapped to a "perfectly smooth" surface as shown in the center. Finally, the polished surface was shot blasted, whereupon the machining marks (vertical lines) and the grinder marks (horizontal lines) reappeared as shown in Fig. 2 at the right. This shows that the material was not uniform in resisting the shot blasting, notwithstanding the long period at carburizing temperature.

There is no evidence at present that the effect brought out by this experiment is significant in fatigue; it is presented here merely to emphasize that there is much that is not known about our materials and processes.

Surface Vulnerable to Fatigue

The surfaces of repeatedly stressed specimens, no matter how perfectly they are finished, are much more vulnerable to fatigue than the deeper layers. It has long been appreciated that the vulnerability to fatigue increases as the surface roughness is increased, particularly if the roughness consists of sharp notches and more particularly if the notches are oriented at right angles to the principal stress. The practice of carefully finishing fatigue test specimens is, of course, a recognition of this vulnerability insofar as visible marks or scratches are concerned. These precautions are known to be effective in increasing the fatigue strength of specimens, and specimens finished in this manner have therefore come to be known as "par" bars. This name

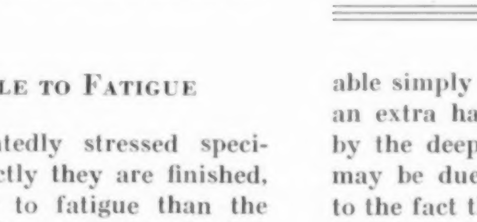


Fig. 3 — O. J. Horger's Experiments on Full Sized Railroad Axles Show Better Endurance When Normally Machined Journals Are Burnished by Cold Rolling. Diagram from A.S.M.E. Transactions, *1936*

implies that fatigue specimens approaching perfection in finish give the highest possible fatigue endurance for any particular material, and that they accurately measure the ultimate fatigue properties of that material.

It can be shown, however, that the so-called "par" bars are not the best specimens, but that influences akin to notches, so far as fatigue vulnerability is concerned, are retained by them. It seems that the specimen surface is highly vulner-

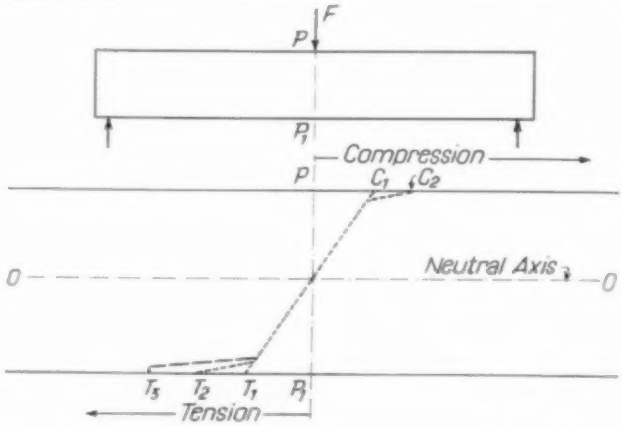


Fig. 4 — Conventional Linear Representation of Stress (C_1-T_1) in a Beam Modified by Lines C_1-C_2, T_1-T_2 and T_1-T_3. Additive Stresses Due to Surface Condition

able simply *because it is a surface* — that there is an extra hazard in the surface layer not shared by the deeper layers. This extra surface hazard may be due to sub-microscopic notch effects, or to the fact that the outer crystals are unsupported on their outer faces. Whatever the reason, the evidence for surface vulnerability is strong.

Compression Lessens Surface Vulnerability — The fatigue strength of the most carefully prepared specimen will be increased if a thin surface layer is pre-stressed in compression by a peening operation such as hammering, swaging, shot blasting, tumbling, or by pressure operations by balls or rollers. This increase in fatigue strength, resulting from the surface layer being stressed in compression, is clearly shown by the *S-N* curves, Fig. 3, which compare normally finished railway axles with axles that had been subjected to a rolling operation. These and other tests show that the surface, stressed in compression, is effective either on highly finished specimens or those with comparatively rough surfaces.

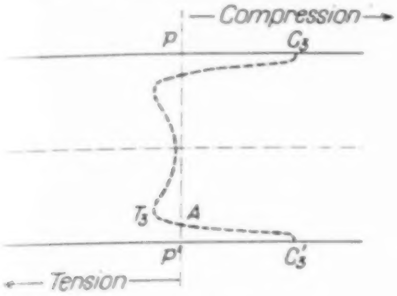


Fig. 5 — Pattern of Residual Stresses in Unloaded Beam That Has Had Its Surface Compressed by Peening

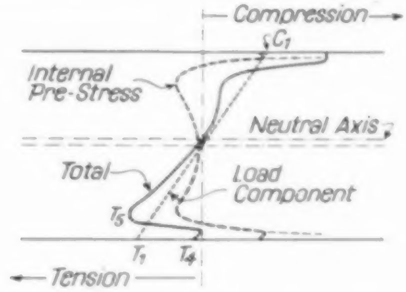


Fig. 6 — The Beam of Fig. 5 Has Been Loaded Once (External Load Equals T_1-C_1), and the Resultant Stresses Are Indicated by Full Line

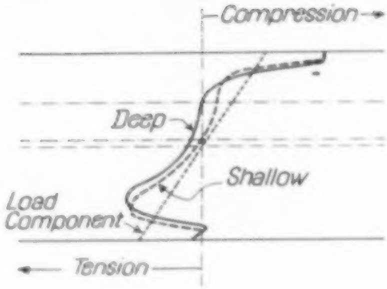


Fig. 7 — Depth of Pre-Stressed Layer Has Considerable Influence on the Working Stress Pattern and the Location of the Neutral Axis

We are all familiar with the improvement in fatigue that may be obtained by a few cycles of overload in such parts as springs. Local stresses from the overloads exceed the elastic limit of the material and, therefore, the tension stress at the working load is decreased. This treatment, which has long been practiced on many production items, is the equivalent of rolling or peening since, in the unloaded state, the member is stressed in compression in the areas where tension yield occurred during the overloading.

The most plausible explanation of the effectiveness of surface compression stress is that when a load is applied to such specimens the tension stress in the surface layer is reduced by the amount of the compression pre-stress, and since *fatigue failure starts only from tension stress* the fatigue durability of the surface layer is increased. However, the tension stress in the material *below* the pre-stressed layer is not reduced but may be actually increased, notwithstanding which the fatigue strength of the specimen is increased. It follows, therefore, that the lower layer is inherently stronger than the surface layer. The German investigator Föppl has shown that the fatigue fracture in cold rolled specimens does not originate at the surface but in the material below the pre-stressed layer, as would be expected if the surface is sufficiently pre-stressed in compression. Similar sub-surface fatigue failures, usually called fissures and attributed to faulty material, have long been known to occur in railroad rails in which the surface is stressed in compression from the cold work of heavily loaded locomotive and car wheels.

The situation can perhaps be clarified by the use of the conventional textbook stress diagram of a loaded beam, as illustrated in Fig. 4, in which a beam supported at the ends is loaded in the central plane, P-P_1. The stress at any point in the beam is measured by the horizontal distance from the plane P, in which the load is applied, to the diagonal line T_1-C_1. The distance P-C_1 represents the compressive stress at the upper surface, the stress at the neutral axis O-O is zero, and the tension at the lower surface is represented by T_1-P_1.

While this is a satisfactory enough stress diagram for static loads, it does not agree with the behavior of fatigue specimens. If we modify the diagram at the ends of the stress line so that T_1-T_2 represents an added increment of tension stress, we have a reasonable representation of the "surface fatigue vulnerability". For a sharply notched surface the additional stress increment T_1-T_2 is relatively great (something like T_1-T_3, where P_1-T_3 represents the yield point of the material). As the surface roughness is decreased the increment T_1-T_2 decreases, but no matter how well polished the specimen may be there still remains a considerable additional surface stress.

Stress Patterns — Figure 5 represents the residual stress pattern in an unloaded beam that has been rolled or peened, as has been described, in which C_3-P and C_3'-P' represent the magnitude of compressive pre-stresses and T_3-A represents the magnitude of the tension pre-stress to balance the compressed stresses in the surfaces. After this beam has been loaded from either side through one stress cycle (as in a reversed fatigue test) the compression pre-stress will be reduced if the applied load raises the total compression stress above the yield point. The stress diagram for such pre-stressed beam supporting an external load is shown in Fig. 6, in which the effective fatigue tension stress T_4 at the surface may be less than the stress T_5 below the surface, in which case failure would start below the surface as observed by Föppl. Note also that the neutral axis is displaced from the geometric center of the beam, and that the tension stress T_5 below the surface is greater than in the beam that had not been pre-stressed, as is shown by the dotted lines.

It seems evident that the improvement in fatigue strength by compressive pre-stress is due to the reduction in tension stress in the vulner-

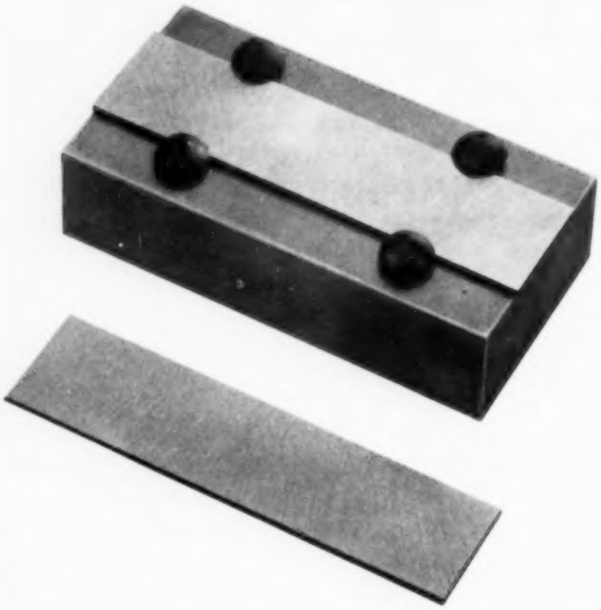


Fig. 8 — Flat Test Strip of Tempered (Stress Free) Steel, Held Down to Stiff Block by Screws so Only One Surface Is Exposed to Cold Working Treatment

able surface layer, and that the increased compressive stress in a specimen stressed from zero to a maximum in either direction does no harm — probably because the compression stress in the prestressed layer is adjusted by the yield of metal.

Further evidence of the extra vulnerability of the surface layer is found in the behavior of specimens having increased strength in a thin surface layer, as in thinly carburized specimens or in thinly nitrided specimens. Fatigue failures in such specimens also start below the surface and show greater fatigue strength than the same material in the unclad state. A nitrided specimen is probably superior to the other forms of hard cladding because, in addition to the higher physical properties of the surface layer, this thin layer is more highly stressed in compression and it is, therefore, less notch-sensitive.

While on the subject of beneficial residual stresses, mention should be made of surface compressive stress obtainable by heat treatment. By a rapid quench it is possible to trap compressive stress in the chilled surface and corresponding tension stress in the core, but this method is not so effective as the others discussed, possibly because of the low yield point of metal at heat treating temperatures.

First Use of Surface Compression

The idea of surface compression to improve the strength of steel is probably as old as steel itself. It has probably been discovered, forgotten and rediscovered many times. Certainly every village blacksmith knew and practiced the art in making wagon and buggy springs, axles and other heavily loaded parts. After these parts were forged into shape they were severely hammered to improve their strength and, no doubt, the same procedure was followed by the ancient sword makers. Likewise, mill and ship shafts were cold worked by the application of small rollers at high pressure, after machining, because of the greater strength that was known to result.

Our technical language contains many words that vaguely describe properties or characteristics of materials or just symptoms that we do not understand. The oil technicians have the handy word "oiliness" for covering up many of the things they do not know about lubricants, the chemists have "catalysis" and the metallurgists have "cold work". We who are interested in fatigue have much to say about "cold work" without regard to the nature of the operation or to the effects that are produced. We often find that "cold work" and "work hardening" are used synonymously. These expressions serve well enough when applied to certain commercial fabrication processes, but engineers must be much more specific when they wish to measure the effect of cold work on fatigue strength.

Fig. 9 — Dial Gage and Knife Edges for Measuring Curvature on Test Strips

Cold working of metals increases the hardness of most metals, including steel, at least in the range of low hardness. It usually results in internal stresses of varying degrees and patterns, it alters the physical properties and sometimes fractures the material. With the known sensitivity of materials to fatigue, we must learn how to control cold work just as we have learned how to control heat treatment, so we may benefit by the good effects and overcome the evil effects. We would not think of specifying a heat treatment without stating whether the temperature should be raised or lowered and to what extent, yet that is the way we now think of cold work. Cold working can be good or bad depending upon how it is done and for what purpose.

Papers have been published showing that cold working the surface, so as to produce a layer stressed in compression, increases the fatigue strength of the parts to which it is applied, but we are not told the *amount* of the pre-stress or the *depth* of the pre-stressed layer. Both of these values are presumably important in obtaining optimum results for any particular specimen, but it is probable that the values should not be the same for all sizes of specimens, for all materials, or for hard and soft specimens.

When the layer is stressed in compression (by applying sufficient pressure on the work by rollers or by peening) to a degree exceeding the yield strength of the metal in compression, the *amount* of residual stress is presumably at least equal to this yield strength.

The *depth* of the stressed layer is probably roughly proportional to the instantaneous area over which the pressure is applied, and to the pressure intensity. The depth of the compression stressed layer in a railroad rail (as studied by E. J. Herbert and reported in the *Journal* of the British Iron and Steel Institute in 1927) should be greater than the depth of the compression stressed layer in the same material if small rollers at the same pressure intensity were used instead of large car wheels. Under these circumstances the initial point of fracture should appear at corresponding depths. Such evidence as is available indicates this to be true.

The magnitude of the sub-surface tension stress in a loaded beam having compression pre-stressed surfaces will vary with the amount of compression pre-stress and with the depth of the pre-stressed layer. Figure 7 shows that the sub-surface tension stress may sometimes be greater for a deeply pre-stressed layer than for a layer of lesser depth. It would therefore seem important to control the compression stressed layer, as to stress magnitude and depth, with considerable accuracy by proper selection of the curvature of the rolling or peening instruments and by the pressure that is applied.

Measuring the Pre-Stressed Layer

A simple and practical method for measuring the magnitude and depth of residual stress in the compression stressed layer consists of a thin flat strip, attached to the heavy base shown in Fig. 8. This strip is rolled or peened with the same intensity that is given to the machine part and when it is removed from the base it will be found to be curved, with the convex surface on the cold worked side. Curvature of the strip may be measured by an indicator, as shown in Fig. 9, which can then be interpreted as a measure of the imposed residual stress.

Figure 10 records as a dashed line and as a full line the stress magnitude and the depth of the stressed layer at constant cold work intensity of two such test strips. To determine the magnitudes the cold worked surfaces of these strips, whose Rockwell hardness was respectively C-64 and C-40, were honed away in small increments and the curvature measured after each thin layer was removed. Because of the higher yield point, the harder specimen was found to be more highly stressed than the softer specimen.

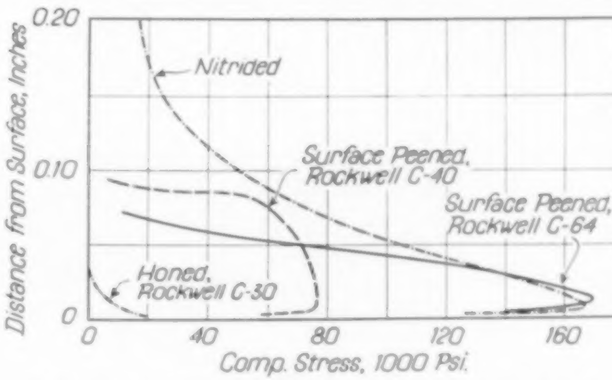


Fig. 10 — Stress Imposed by Various Treatments

Also shown in this chart is the surface compressive stress set up by nitriding. Procedure for this experiment was the same except that the face of the specimen that was in contact with the heavy base was tin plated to prevent nitriding. On removal from the base the strip was curved convex on the nitrided side. It seems, therefore, that the well known resistance of nitrided specimens to fatigue is primarily due to the compressively stressed surface layer.

Residual Stress From Honing — While the above described peened specimens were being honed it was found that the strips did not fully recover their original flat form. To determine if this residual curvature was due to a "set" in the material, or was the result of honing, other flat strips that had not been peened were honed. These strips developed the same curvature as the residual curvature in the peened specimens, demonstrating that honing produces a compressively stressed layer. The approximate magnitude of this stress is also shown in Fig. 10. This observation raises a question as to the state of surface stress in the carefully prepared and lapped specimens favored for laboratory fatigue tests, since additional tests have shown that lapping also introduces surface compressive stress.

The Carburized Layer in a carburized part is stressed in compression, as is shown in a simple test. Two opposite faces of a ½-in. square specimen were carburized while the other two faces were protected by copper plating. The specimen was quenched and tempered *(Continued on p. 270)*

BIOGRAPHICAL NOTES OF EMINENT METALLURGISTS

Herbert James French

PRESIDENT, AMERICAN SOCIETY FOR METALS

THE PRESIDENT of the American Society for Metals, installed in this office last October, is described by one of his good friends as "an easy-going gentleman who is 100% relaxed 100% of the time". That does not mean, of course, that he has not the ability to hold fast to the things he believes in, and fight the good fight — merely that this characteristic of never coming within gunshot of losing his temper, even in the most adverse circumstances, is responsible for his extreme popularity within the metallurgical profession.

Herbert French's interest in the ⊕ has been continuous since 1921, when he joined the Washington Chapter of the newly consolidated American Society for Steel Treating. Next year he became secretary-treasurer of the Chapter, and the next its chairman. He was one of its famous "Four Horsemen"; with Paul McKinney, H. W. Gillett and Jerome Strauss, he completed a quartet always prepared not only to open but to maintain discussion on the paper presented by the visiting speaker. Volume II of the *Transactions* carries no less than four contributions from the pen of this young physicist at the National Bureau of Standards on such important topics as the properties of alloy steels at high temperatures, the heat treatment of carbon toolsteel, steels with the new alloying element molybdenum, and lathe breakdown tests of high speed tools. This literary pace could not be maintained, but there is hardly a volume of *Transactions* that does not have a scientific paper from him, culminating with the "Study of the Quenching of Steels" which was awarded the Henry Marion Howe Medal in 1930.

A characteristic which became more and more apparent during these years was his knack of getting things done and his ability to plot and replot test data in various fashions until he had squeezed the last possible bit of information from them. One of the men who worked under him used to say, "He sure can milk the data dry!"

He was appointed Campbell Memorial Lecturer for 1933 and spoke on "Fatigue and the Hardening of Steels", presenting much experimental evidence to clarify hazy notions about conditions causing incipient damage in the metal. In 1941 he gave a series of lectures before the Fourth Western Metal Congress in Los Angeles, and these have been published in a book entitled "Alloy Constructional Steels".

In addition to his contributions to the Annual Conventions' technical sessions, he was almost continuously serving on cooperative committees, representing the ⊕ (then still the American Society for Steel Treating) for years on an advisory committee to the War Department, and later on special research committees on the cutting and forming of metals. He was elected trustee of the national society in the fall of 1939.

HERBERT JAMES FRENCH was born in New York City on May 27, 1893. He attended Horace Mann School and the School of Mines at Columbia University. From the latter he received the degree of Metallurgical Engineer in June 1915.

His first professional experience was as a chemist and assayer with American Smelting and Refining Co. at Murray, Utah. Returning east, he became metallurgical engineer for a subsidiary of the General Electric Co. known as the General Vehicle Co. in Long Island City. This company manufactured electric and gasoline trucks, and at the outbreak of World War I made the then well-known Gnome airplane engine for the Allied Nations. In their manufacture the young metallurgist came in contact with the first problems of importance concerning aircraft engine alloy steels presented to American industry.

In 1917 French was appointed to the Signal Corps, United States Army, as a civilian inspector of materials. He continued in this work when it was later absorbed into the Bureau of Aircraft Production. As an airplane inspector he was introduced to plywood construction monocoque fuselages and had his first ride in a "crate". Later he was assigned as district inspector in Philadelphia for the Pittsburgh (Ordnance Metallurgical) office, and still later transferred to Pittsburgh to inspect tubing and solve production problems. Among his associates there were the late George L. Norris, long with the Vanadium Corp. of America; A. K. Hamilton, who until his death some years ago was president of the Treadwell Engineering Co. of Chicago; Earle C. Smith (now chief metallurgist of Republic Steel Corp.); Elmer Larned (now metallurgist at Youngstown Sheet and Tube Co.'s Indiana Harbor plant); Fred W. Krebs of Super Steels, Inc. of Cleveland; Harry D. Weed, now in Chicago for Simonds Saw & Steel Co.

At the end of the war, French was given the opportunity of joining the Metallurgical Division of the National Bureau of Standards, where he expected to remain under George K. Burgess for about six months so as to gain some experience in the type of research for which the Bureau was noted. He stayed in Washington ten years; when he left, he was assistant chief of the Metallurgical Division. In 1929, he joined the staff of the research laboratory of the International Nickel Co., Inc. at Bayonne, N. J. Two years later he was transferred to the New York office in charge of alloy steel and iron development.

Early in 1942 he was invited by Carl Adams, then chief of the Iron and Steel Branch of the War Production Board, to come to Washington and for some months he was chief of the Metallurgical and Specification Section. *(Continued on page 272)*

The following paper discusses the economic considerations leading to the satisfactory substitution of a welded alloy steel basket for a synthetic ammonia converter formerly made of a large seamless forging. It is one of the prize-winning papers from the recent $200,000 Industrial Progress Award Program conducted by the James F. Lincoln Arc Welding Foundation.

AMMONIA CONVERTER OF WELDED 5% CHROMIUM STEEL

BY J. SCHUYTEN
Metallurgist, Shell Chemical Co., San Francisco

THE VESSEL to be described is an inner drum in a synthetic ammonia converter and contains a tube bundle and a catalyst mass outside of the tubes; it constitutes, therefore, both an internal heat exchanger and the reaction chamber where the ammonia is formed from its constituent gases. It is a cylindrical shell 45¼ in. outer diameter and about 23 ft. long, with thickened ends for stud bolts to fasten the top tube sheet and bottom cover. The vessel is subjected to a H_2-N_2-NH_3 atmosphere at 950° F. max. and 1650 to 2000 psi. pressure; the pressure, however, is substantially the same on both sides of the vessel.

These vessels were originally seamless forgings of carbon steel, S.A.E. 1030. As carbon steel is subject to an insidious form of disintegration known as hydrogen attack when subjected to hydrogen-containing atmospheres at these temperatures and pressures, it was determined to improve upon the original construction when ordering replacement vessels. Considerable cooperative work with the prospective manufacturer resulted in the adoption of a vessel fabricated by arc welding, made from a high grade hydrogen resistant alloy steel of the 4 to 6% Cr type, and welded with high alloy electrodes of 25% Cr, 20% Ni, 55% Fe.

The most striking feature in seamless forging is the number and complexity of the steps involved in manufacture. The approximate sequence of operations is:

1. Forge.
2. Normalize, anneal, and test for physical properties.
3. Rough turn and rough bore.
4. Anneal for strain relief.
5. Rough turn and rough bore with fairly close allowance for final machining.
6. Drill bolt holes.
7. Anneal for strain relief.
8. Final machine to dimension.
9. Tap bolt holes.

In considering the first of these operations, the comparatively simple word "forge" covers a series of arduous and time-consuming steps. Firstly, an ingot of sufficient size to insure adequate forge reduction is required; secondly, the ingot must be upset and the center hole punched out. Subsequently, the forging is forged over a mandrel, requiring numerous reheatings before the piece is finished to rough dimensions.

The subsequent machining steps with intermediate anneals are necessary to eliminate the deleterious effect of internal stresses remaining from the forging and machining operations. The amount of machining required even with relatively heavy cuts can be readily appreciated from the dimensions of the vessel. Summarizing, it may be concluded that the process in general is prodigal of man-hours, time, and material.

Deterioration of carbon steel in hydrogen atmosphere takes the form of severely reduced

physical properties and sharp decarburization and fissuring of the grain structure, due to reaction between hydrogen and various constituents in the steel, notably carbides, oxides, and sulphides. Tensile properties of a core removed from one of these vessels after 37,848 hr. in service as compared with the specified originals are:

	Specified	After Hydrogen Attack
Yield point	35,000 psi.	23,900 psi.
Tensile strength	60,000 psi.	23,900 psi.
Elongation	25% min. in 2 in.	0.0%
Reduction of area	50% min.	0.0%

It is noted that the tensile bar showed no ductility whatsoever, and sharply decreased and coincident values of yield point and tensile strength. The severe fissuring and total decarburization are progressive actions. Representative conditions at both inner and outer surfaces are reproduced in Fig. 1 and 2.

An additional and related service defect which contributes to placing a limit on the useful life of this type of vessel is the warpage and out-of-roundness which inevitably ensues upon long exposure to severe operating conditions.

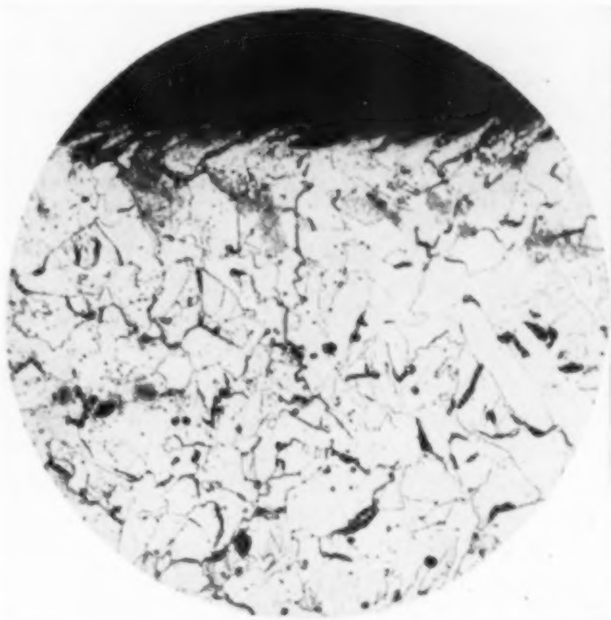


Fig. 1 — Intergranular Fissures and Voids at Surfaces of Forged Steel Tube Used in Ammonia Synthesis. Nital etched; 100 magnifications

New Type of Construction

The requisites of a new type construction were considered to be *(a)* immunity to hydrogen attack, *(b)* lower cost and *(c)* greater simplicity of manufacturing operations.

Arc welding seemed the logical answer to these requirements; in this way, a high grade of hydrogen-resistant alloy steel plate could be economically rolled and fabricated into the required cylinder, and the end rings could be rolled, welded to the cylindrical shell, and machined as required. An electric furnace alloy steel was settled upon as the plate material, with the following analysis*: C 0.10% max., Si 0.50% max., Mn 0.50% max., Cr 4 to 6%, Mo 0.40 to 0.60%, Al 0.25% max., P <0.03% and S <0.02%.

Welding was to be done with the shielded arc method with electrodes of 25% Cr, 20% Ni stainless steel (0.10% C max.), a material which, as deposited, gives a strong, ductile seam with corrosion resistance higher than that of the parent metal.

Numerous practical problems arose which required solution. Firstly, the air hardening propensities of the 5% Cr + Mo steel complicated the welding procedure by requiring a high degree of preheat and a relatively high stress relieving treatment. In order to restrict the air hardening tendency 0.25% aluminum

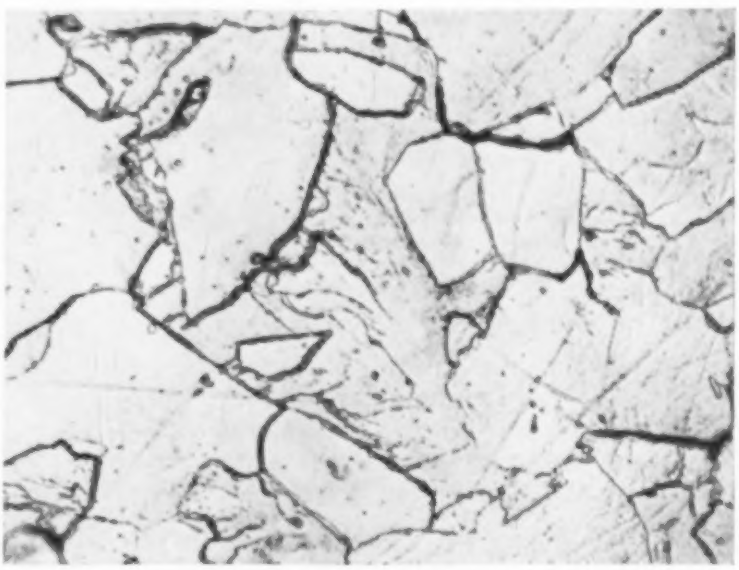


Fig. 2 — Total Decarburization at Surface of 0.30% Carbon Steel Forging After 37,848 Hr. Exposure to H_2-N_2-NH_3 Atmosphere at 950° F. and 2000 Psi. Nital etched; 500 dia.

*Check analysis showed C 0.08%, Cr 5.11%, Mo 0.43%, Al 0.31%.

was added; thus the preheat could be safely reduced to 150 to 200° F. before welding, and the stresses satisfactorily relieved at 1150° F. Specifications as finally established called for a 2-hr. soak at this temperature, with subsequent cooling rate of 50° F. per hr. max. to 1000° F., and further cooling in the furnace. Preheating was done by gas torches and was continuous to the time of stress relieving.

Attention had to be given to the nature and magnitude of thermal stresses originating in the widely different coefficients of expansion of parent metal and weld metal. Stresses arising from differential expansions in circumferential, longitudinal, and radial directions were calculated and it was found that only the stresses in the radial direction were of significance. The maximum shearing stress on the fibers adjacent to the weld was determined to be on the order of 5000 psi., which was considered permissible.

In order to weld with a single V joint the cylindrical wall thickness was reduced to ¾ in. Welding was performed against a backup chill strip, 1 in. wide, of 18-8 stainless steel which in turn was alloy tack welded inside the shell. The finish weld was $\frac{7}{16}$ in. wide at the inner wall and ¾ in. wide at the outer wall; each joint was made with two passes with $\frac{3}{16}$-in. rod and the remaining passes with ¼-in. rod. All welding was done manually by certified welders.

It was further considered desirable, for maximum stability at high operating temperatures, to have the metal in the completely annealed condition, which would correspond to a microstructure consisting of spheroidized carbides and ferrite. In order to insure this condition a maximum of 150 Brinell hardness was specified for the plate material. The plate was therefore ordered in the hot rolled, fully annealed condition, pickled free of mill scale.

The purchaser's drawing merely gave the general dimensions of the cylinder and details of the ends. The drawing, Fig. 3, is adapted from the manufacturer's drawing indicating

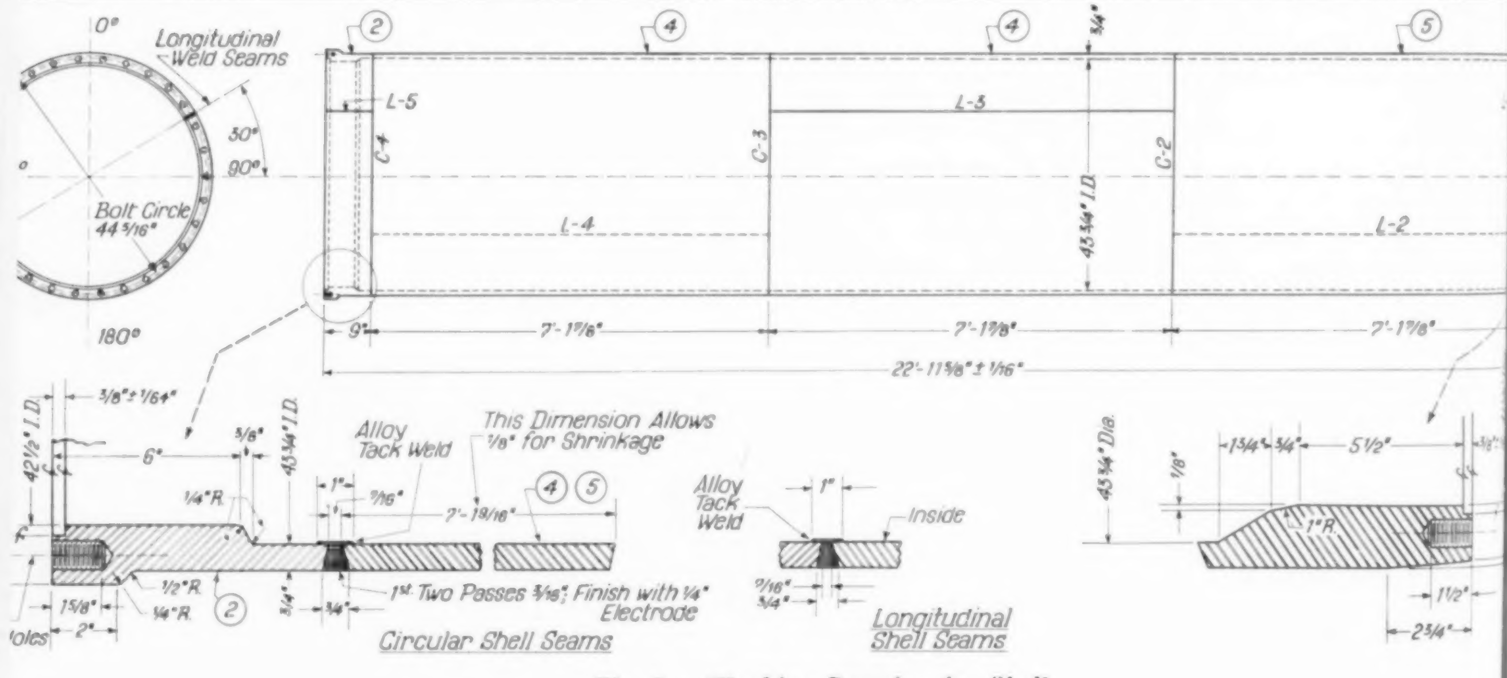


Fig. 3 — Working Drawing for Shell

Notes on Construction: All welds to be made with 25% chromium, 20% nickel weld rods.

Preheat to 150 to 200° F. before welding longitudinal shell seams; 200 to 250° F. for longitudinal seams in end flanges. Preheat shell rings to 200 to 250° F. before welding circular seams, and maintain this temperature up to time of stress relief.

Stress relief of completed vessel: Heat to 1150° F.; hold 2 hr.; cool at less than 50° F. per hr. to 1000° F.; shut off burners and cool in closed furnace thereafter.

Finish the machining after the stress relief heat treatment, then sand blast inside of cylinder.

Dimensional tolerances of shell sections:

Minimum diameter, not more than ⅛ in. under nominal diameter.

Maximum diameter, not more than ⅛ in. over nominal diameter.

Tolerance on circumference, +⅜ in., −0.00 in. on nominal circumference.

Maximum difference in diameter at any one cross section not to exceed ¼ in.

Maximum deviation from normal center line not to exceed ¼ in. for entire length of vessel.

location of welded seams and showing details of the welded joints. Some further details are given in the caption.

Fabrication Routine

The steps which were involved in the fabrication of this vessel may be outlined as follows:

1. Roll shells and end rings from rolled plates; *(a)* shells to be rolled cold and *(b)* end rings to be rolled at a temperature between 1000 and 1500° F.
2. Weld longitudinal seams in end rings and in each shell section; preheat as noted.
3. Stress relieve as separate units.
4. Remove backing strips and grind welds flush.
5. Re-roll shells cold. Re-roll end flanges hot; temperature between 1000 and 1500° F.
6. Rough machine the end-rings.
7. Assemble shell and weld all circumferential seams.
8. Stress relieve.
9. Finish-machine the end flanges; drill and tap bolt holes.
10. Grind all welds smooth and flush.

The results of tensile tests on the plate used for the first welded vessel are compared in the adjoining table with the specifications under which they were ordered. A test plate was welded under identical conditions with the longitudinal seams, and was stress relieved with the vessel.

The bend test was to bend cold to 180° around a round mandrel whose diameter is equal to 2½ times the thickness of the plate.

Brinell hardness was specified as 150 (Rockwell B-79 to 80); the sides of the vessel as delivered measured 147 to 152 and the end rings were 153 to 162. Hardness traverse across a weld, as made by the purchaser, showed very slight hardening at the weld junction:

Mm. from centerline	0	2	4	6	8	10	12	14	16	18
Rockwell, B scale	99	97	97	97	93-96*	85	82	81	80	80

*Junction, weld and parent metal.

Dimensional Tolerances

Due to the nature of the service to which this vessel will be subjected, it is very essential that the tolerances be kept at the absolute minimum possible. Therefore, circumferences and diameters were measured at 11 critical points along the length of the completed vessel. The difference in diameters at any one cross section varied from a minimum of 0 in. to a maximum of ¼ in.; the maximum permissible difference of ¼ in. was reached at only one point. Circumferences varied from −0.00 to +⅜ in. on the nominal value. The maximum deviation from normal centerline over entire length was less than ¼ in.

Micro-examination of a piece cut from the test plate disclosed (Fig. 4 and 5, page 222) a parent metal consisting of a fine grained, low carbon structure of spheroidal carbides in a ferrite matrix. Both the weld and the line of fusion between weld and parent metal were sound throughout (Fig. 6).

Tensile Tests After Stress Relief (2 Hr. at 1175° F.)

Bar	Yield	Ultimate	% Elongation	Reduction of Area
Specification				
Parent metal	>30,000 psi.	>65,000 psi.	30 in 2 in.	60%
Weld metal	....	....	25 in 2 in.	..
Manufacturer's Tests				
Weld metal	65,100	97,800	36 in 2 in.	50
Parent metal	38,400	69,000	51 in 2 in.	..
Purchaser's Tests				
Weld metal	71,600	104,500	36 in ⅝ in.	55
Junction, weld and parent metal	60,200	98,200	38 in ⅝ in.	50
Parent metal	35,800	70,000	43 in ⅝ in.	74

Macro-etching disclosed a heat affected zone adjacent to the weld 1.5 mm. wide. In general, judging from physical and metallographic tests, it may be said that the welding was very satisfactory.

Economic Considerations

The most fundamental difference between the seamless forged construction and the welded construction lies in the simplicity of the manufacturing operations involved in the latter as compared to the former. Fabricating from rolled plate by arc welding reduces the number of operations and the manufacturing time to a fraction of that formerly required. The plate may be purchased on the open market, and the total time consumed from arrival of material to completion of vessel need not exceed two weeks.

Cost data bear out the above contentions. The purchaser is in no position to present a

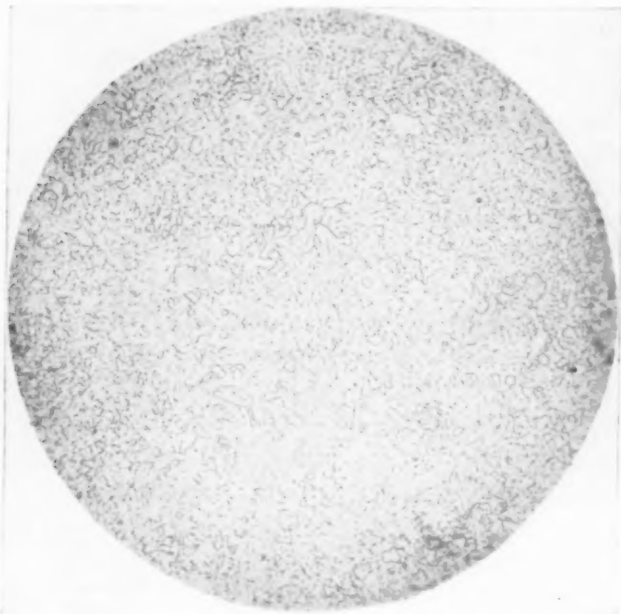
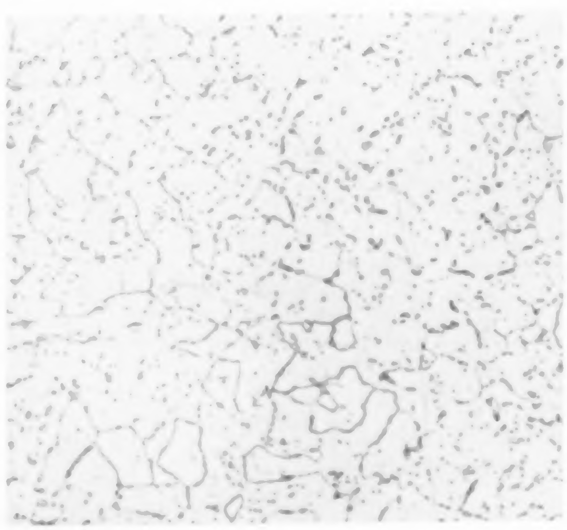


Fig. 4 (left) — Fine Grained Structure, at 100 Diameters, of 5% Cr-Mo-Al Steel Plate Used for New Vessel. Fig. 5 (center) — Same, Magnified 500 Diameters, to Show Spheroidal Carbides in Matrix of Ferrite



complete breakdown of manufacturing costs; however, the quotations submitted may be considered as reliable criteria of respective manufacturing costs. A forging manufacturer's quotation of March 13, 1940 for one forged drum of carbon steel, estimated weight 11,200 lb., was \$10,580. A welded vessel manufacturer's quotation of June 20, 1940 for one welded catalyst basket of alloy steel, estimated weight 9100 lb., was \$5,007, and for lots of two the quotation was \$4,670 each.

Therefore, when ordering one vessel at a time, the percentage saving in cost, figured on the original construction, is 52.7%.

It should be remembered that the welded vessel is made of a high grade electric furnace alloy steel whose normal ratio of cost to ordinary carbon steel would vary from 3.3:1 to 4:1 for standard plate, bars, tubing and shapes. This fact makes all the more significant the difference in cost between the two types of construction.

Up to the time of writing two alloy vessels of welded construction have been purchased, one of which was placed in service in June, 1941.

In the above no account was taken of the fact that the new equipment is inherently superior in its service life expectancy due to its resistance to hydrogen attack. The forged carbon steel vessel was permanently removed from service after some 50,000 hr. of service life.

In estimating the useful life of the welded alloy steel vessel, a guide is provided by a service test in the process stream of sample welded pieces of the identical alloy and the welding technique. After exposure of some 9000 hr. no effect on the weld or the junction of weld and the parent metal could be found.

There was a very thin nitrided skin on the parent metal due to the ammonia in the gas and the stability of the

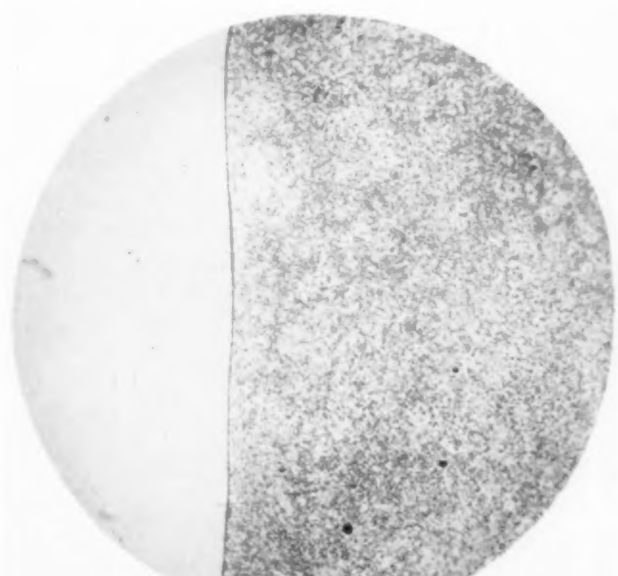


Fig. 6 — Junction of Weld Metal (at Left, Unaffected by Nital Etchant) and Parent Metal. The preheat and post-heating technique has avoided any hard martensite at the joint. 100 magnifications

nitrides of chromium, molybdenum, and aluminum. This skin is very thin and is not considered harmful.

It may safely be concluded that the service life of the welded alloy steel vessels will be at least twice that of the carbon steel forgings, and very probably much more.

In order to appreciate the significance of this change in design from seamless forged construction to welded construction, it is necessary to understand that a deeply rooted prejudice has existed, directed against any and all welding in a high pressure synthetic ammonia plant. This prejudice, however, has a very real basis, as welding will frequently render an otherwise resistant steel susceptible to hydrogen attack. In the case under discussion the materials chosen for the vessel body proper and the welding electrodes are both practically immune to hydrogen attack, both before and after fabrication by welding, and, therefore, this factor ceases to be a consideration.

Rapid Fabrication and Delivery

From the standpoint of the ultimate consumer there is one more all-important consideration, a factor which under present conditions looms even larger than cost — namely, availability. The delivery which can be obtained from the manufacturer is of prime importance; here again the welded construction demonstrates its superiority. A heavy forging of this nature can be made by only a very few manufacturers, and they are at present completely engrossed in manufacturing heavy ordnance for Army and Navy. Fabrication of equipment by arc welding then, in addition, is instrumental in alleviating a difficult shortage of production facilities.

This discussion covers only one instance where arc welded construction proved superior to seamless forged construction. It should be pointed out that the substitution of welded vessels for forged vessels in chemical industry has received a profound impetus from the appearance of the multi-layer type of pressure vessel made up of layers wrapped and welded in succession. This development of the A. O. Smith Corp. may, by the proper combination of alloy inner layers, gas venting arrangements and other design details, be utilized for the fabrication of many high pressure, high temperature vessels which heretofore have been reserved for seamless forgings.

LEAD EQUIPMENT USED IN INDUSTRY★

BY F. E. WORMSER
Secretary, Lead Industries Association

LEAD and some of its alloys are extensively employed in the construction of equipment for the production, transportation, storage and use of many corrosive chemicals. Following is a list of some more or less common chemicals in contact with which lead or its alloys have been used successfully:

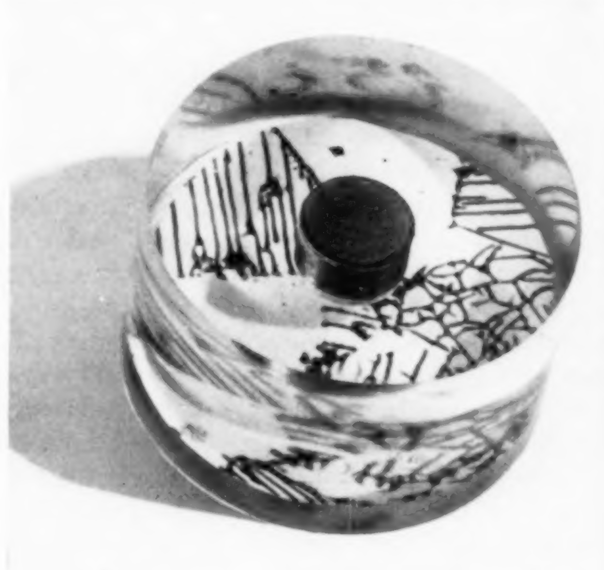
Aluminum sulphate	Reductions
Ammonia vapor	Sodium bisulphate
Ammonium sulphate	Soldium chloride solution, or sea water
Antimony tri-chloride	Sodium hydrosulphite
Bleach liquors	Sodium hyposulphite
Brown acid mother liquor	Sodium sulphate
Carbonate, soluble	Sodium sulphide
Chlorine gas	Sodium sulphite
Hydrofluoric acid	Sulphonations
Koch's acid	Sulphur chloride
Mixed acids	Sulphur dioxide
Nitration mixture of H-acid	Sulphuric acid
Para-nitrophenol	Sulphurous acid
Phosphoric acid	Sulphuryl chloride
Phosphorous chloride	
Zinc chloride	

This is by no means a complete list of chemicals with which lead may be or has been used, nor does it signify that lead is necessarily satisfactory with all the listed chemicals under every circumstance. Because conditions vary so widely from plant to plant and process to process, it is always wise to judge each installation on its own merits and, if possible, to make tests under actual operating practice. Among the many variables determining the suitability of lead, or any other material for that matter, may be temperature, concentration, grade of lead or type of alloy, rate of flow, presence of oxygen, degree of abrasion, and presence of impurities.

It is important in selecting lead for corrosion resistant equipment to decide upon the correct grade or alloy for the purpose. If unalloyed lead is used, it is generally one of the A.S.T.M. grades known as chemical lead, acid lead, or copper-lead. These grades differ from corroding and common lead mainly in the copper *(Continued on page 262)*

★A manuscript prepared for the next edition of Metals Handbook.

BITS & PIECES



Small Sample of Alloy (72% Mn, 18% Cu, 10% Ni) Mounted in Lucite Above an Acceptable Photomicrograph, so a Beginner Can Appraise His Own Polishing and Etching. Photo about double size

COMPUTATIONS OF HARDENABILITY

UNDISSOLVED CARBIDES, remaining in a piece of steel after commercially suitable heat treatments, are likely to throw out of kilter any computations of hardenability based on chemical analysis. For a case in point take the end-quench hardenability curve for S.A.E. 6150 which is straddled by curve for NE9440 and 9450 (*Metal Progress*, November 1942, page 857). However, when hardenability is figured by the methods summarized in the Data Sheet, page 660 of the October issue, 6150 is just hardenable to the center of a 3-in. round in an ideal quench, while 9445 would harden in 4½-in. rounds.

I would assume that the difficulty is that there is no way of estimating the amount of undissolved carbides in these steels. If that is a correct assumption there would also be a whole host of steels liable to have undissolved carbides (particularly the Cr-Mo and the Cr-V combinations). Has anyone had difficulty in checking Jominy curves against Grossmann hardenability in such instances?

METALLURGICUS.

AN AID FOR TEACHING METALLOGRAPHY

IF ONE STAYS IN A JOB long enough he is always studying methods to make work easier — and that goes for the job of teaching.

At the start of each course on metallic alloys, the student first must learn to polish and etch samples of typical alloys. After he finishes his first assignments he always has to ask whether or not the job is done satisfactorily.

To eliminate most of these questions I have mounted alloys in lucite, with a small area of a good photomicrograph mounted near the back. All the student has to do is to compare what he has developed with the structure shown with each alloy. Simple, isn't it? (CHARLES Y. CLAYTON, Department of Metallurgical Engineering and Ore Dressing, Missouri School of Mines and Metallurgy.)

MEASUREMENT OF CASE DEPTH

IT WOULD APPEAR that the six methods of measuring case depth, listed in the September and November "Bits and Pieces" are enough, but none of them is without criticism.

In our opinion effective case depth is that depth to which a part is harder, when properly quenched, than it would have been had it received the same thermal treatment without carburizing. We believe that this definition most satisfactorily covers the wide range of steels, from 0.10 to 0.40% carbon, being casehardened at the present time.

Practically, we read case depth by fracturing the part in the condition in which it will be used. We etch the fracture in 1% or 5% nital, which darkens the case and leaves the core light. (This is faster and generally better than heat tinting.) Depth is measured in thousandths

with a 40× measuring microscope. For depths over 0.020 in. a Brinell glass is adequate. Samples with cores over C-30 must often be polished to be accurately read.

We check our carburizing practice on certain products by microscopic examination of slowly cooled samples. In estimating case by this method, we read as far toward the core as there is an obvious excess of pearlite grains due to carburization. For most heat treating specifications the two methods check. (JOHN W. WATSON, Metallurgical Dept., Ewart Plant, Link-Belt Co.)

AVOIDING SCALE ON END-QUENCH TEST PIECE

IN MAKING THE JOMINY TEST for hardenability accurate results are dependent on keeping the end of the specimen, which is to be quenched, free from scale while it is being heated. Recommended methods are to place the specimens while heating either on a block of graphite, or on a layer of cast iron chips. When heating in an electric muffle the graphite block produces a reducing atmosphere and may impair the life of the resistors or thermocouples. And cast iron chips may become oxidized and stick to the end of the specimen, causing as much trouble as the scale they are supposed to prevent.

Both of these difficulties have been avoided in our laboratory. We prepared six cups from some scrap-ends of 25% chromium-iron bars, the inside diameter being $\frac{1}{16}$ in. larger than the hardenability test specimen, and the depth of the hole about 3½ in. The outside of the closed end must be flat so the cups will stand upright. These are set up in the heating furnace while it is coming to temperature, and the hardenability test specimens placed in them, fitting rather closely, and the circulation of air is so slight that the specimens scale chiefly at the top end where it does not matter. The bottom end, which is to be quenched, remains protected and practically free from scale.

Six of the cups are sufficient no matter how many tests are to be made, assuming that only one specimen can be tested at a time, since the heating period is 60 min., the tests require 10 min., and when one specimen is taken out of a cup for quenching another one can be put in. The alloy cups do not scale very much at quenching temperatures, and they last a long time. Since nothing need be used inside them to prevent scaling of the bottom end of the specimen, provided there is a reasonably close fit between the specimen and the cup, nothing can stick to the bottom of the specimen to interfere with the quench. It does not seem to be necessary to have these cups covered at the top, or to have them longer than about 3½ to 4 in. (GEORGE F. COMSTOCK, Metallurgist, The Titanium Alloy Mfg. Co.)

MEMORY AID FOR WELDERS

STUDENTS have a hard time remembering current settings for electrodes of different diameter due to the fact that the present heats given for electrodes vary somewhat in range as well as the fact that there are many electrode types produced by different manufacturers. It has proved very difficult for even an experienced welder to remember all these currents. The data may be simplified as follows so that one has only three currents to remember:

DIAMETER OF ELECTRODE	CURRENTS FOR ORGANIC COATED ELECTRODE, REVERSE POLARITY
⅛ in.	20 to 110 amperes
$\frac{5}{32}$ in.	120 to 140 amperes
$\frac{3}{16}$ in.	140 to 160 amperes

Bare electrodes will require currents 10% higher than electrodes of reverse polarity, while straight polarity will average 5% higher. Mineral coated electrodes, which can be used with a.c. or d.c. current, will need 20 to 25% more current than the reverse polarity class as shown. Keeping these sizes and currents in mind, one can apply his common sense for smaller and larger electrodes, if used. He should also take into consideration the thickness of plate or shape being used on the particular job. In some types of production welding, heats (currents) are slightly higher, but the general trend in that line is for welders to use too much current. (JOSEPH V. KIELB, Welding Engineer, Harrison Radiator Division, General Motors Corp.)

"Bits & Pieces" (Metallurgicus' Own Page) is designed for small but useful notes on things that have troubled ASMers and how to avoid them. Send in your own. The reward is any ⊕ book (except the Handbook)

RADIOGRAPHY AS AN INSPECTION TOOL

Outlines Presented at Panel Discussion at ⊕ Convention, Cleveland, Oct. 13, 1942

X-RAY INSPECTION ON A PRODUCTION SCALE

BY TOM A. TRIPLETT
President, Triplett & Barton, Inc.
Burbank, Calif.

STANDARDIZATION of technique and material in production, I believe, can be stated quite concisely by the following:

Production standardization is the analyzing and development of a certain skill or skills, of either an individual or a group of individuals, then transferring or engineering these skills into machines, equipment, processes, or procedures, so as to insure a greater production with infinitely less variations than those produced by these individuals themselves. To gain the most from this process, it must be continually simplified.

As applied to industrial radiographic work, I am afraid that the time allotment is insufficient to cover this subject in any detail. However, an outline of how we, as a group, operate may serve to illustrate the above.

Outside of the management, there are several departments in our organization with distinct functions:

1. *Research Division,* whose task it is to develop and test the value of old and new methods in connection with X-ray work, and to make measurements in every phase of the X-ray process.

2. *Engineering Division,* to design or otherwise put these ideas into machines or procedures.

3. *Test Group,* composed of complete physical, chemical, metallurgical, spectrographic, X-ray diffraction, electrical and other laboratories, whose function is to run continuous correlation tests of all processes, and particularly those involving the radiographic appearance as connected with physical strengths, or with foundry practices that have formerly caused rejections.

4. *Cost and Tabulating Department* runs continual cost analysis, as well as statistical data on rejections by part number, material, foundry, and other identifiable major factor.

5. *Production Department* is broken into the following divisions:

- A. Handling of material.
- B. Technique setting.
- C. Raying of material.
- D. Film processing.
- E. Interpretation of film.
- F. Office work and report writing.

6. *Inspection and Maintenance Department* insures that equipment and procedures are kept up to standard at all times.

7. *The Coordination Department,* whose function is to correlate the various endeavors of all other departments into a smooth working unit. This department is also charged with providing a written procedure for each job and process, particularly those engaged in production work.

One of the results of this arrangement has been the establishment of what we believe is the highest production X-ray laboratory in the United States. Each of its four branches is also higher in production capacity than would otherwise obtain. And, by the way, this has been done without any Government financing.

Other results are the recognition of the need for and the development of fine focal spot, low scatter X-ray tubes; the first automatic X-ray machines; the first automatic film processing machines, including chemical control of solutions; small, light-weight equipment; and completely portable X-ray and dark room equipment for working out in the field.

Auxiliary results of this production standardization include the recognition for the need and the fostering of the development of fine-grain, high contrast, X-ray film, and the need for adequate instruments and basic measurements for various processes and materials connected with X-ray work. We have also established a research foundry to enable us to find what to do, or not to do or recommend, to prevent defects or rejections.

Another essential and logical outgrowth has been an educational system for raising the skills of persons in our organization.

ACCEPTANCE STANDARDS FOR LIGHT ALLOY CASTINGS

BY W. H. BURROUGHS
Assistant Chief Inspector
The Glenn L. Martin Co., Baltimore, Md.

IN ORDER to have a clear understanding of this phase of the use and interpretation of radiography as an inspection method, it is necessary to review the various factors which are involved in the acceptance and rejection of light alloy castings. Most of these factors are not peculiar to light alloys, but are generalizations which apply to the entire field of interpretation of X-ray negatives of cast products.

The three major factors involved in acceptability are as follows:

1. Design load.
2. Simulated load test.
3. Type and location of defect.

The Design Load, as determined by stress analysis, must be thoroughly understood by the person who must interpret the X-ray negative. The *magnitude* of the load, as well as its direction, has a very important bearing on the decision as to acceptability or rejection of the part. The *type* of loading, such as tension, compression, or shear, must be taken into account in the final analysis of the acceptability of the part. The *method* of applying the load to the part is also an important point to know; that is, whether the load is static or vibratory, for since the ability of the part to withstand repeated reversals of loading is different from its ability to take a static load, the method of application of the load must be considered in the ultimate analysis.

The Simulated Load Test should be run to destruction on any part before any attempt is made to determine its acceptability under definite inspection standards. The test should, as near as possible, reproduce the actual conditions of operation to which the part will be subjected in service. It is important to remember that tests run on samples machined from a casting are not related to the serviceability of the part, and cannot be correlated with the interpretation of the X-ray negative. This is due to the deviations to be found in different sections of the casting due to variations in the solidification structure, the heat treatment, thickness of section, and the function of the section in question with respect to the entire casting. On the other hand, the actual area of failure will be designated clearly in a simulated load test. There is and must be a distinct correlation between the results of load tests and the visual interpretation of the negative before the castings can be accepted or rejected on this basis.

The Type of Defect present in the casting in question must be considered in the final decision. Discontinuities commonly referred to as "defects" which occur in lighter alloy castings are more conveniently divided into two types. These are general defects and localized defects. They will be summarized briefly in the same relative position as listed above.

General Defects

1. *Blowholes* are gas holes which usually appear as large spherical or rounded darkened areas with well-defined borders. These are random in occurrence but usually tend to distribute on the cope side of a casting. The interior of these holes usually presents a very smooth appearing surface.

2. *Dross* or oxide inclusions appear as small darkened regions of very irregular and indistinct outline. As this irregularity is in two planes, the density of the film will vary. They tend to be random in occurrence but sometimes are localized in the cope side of the casting.

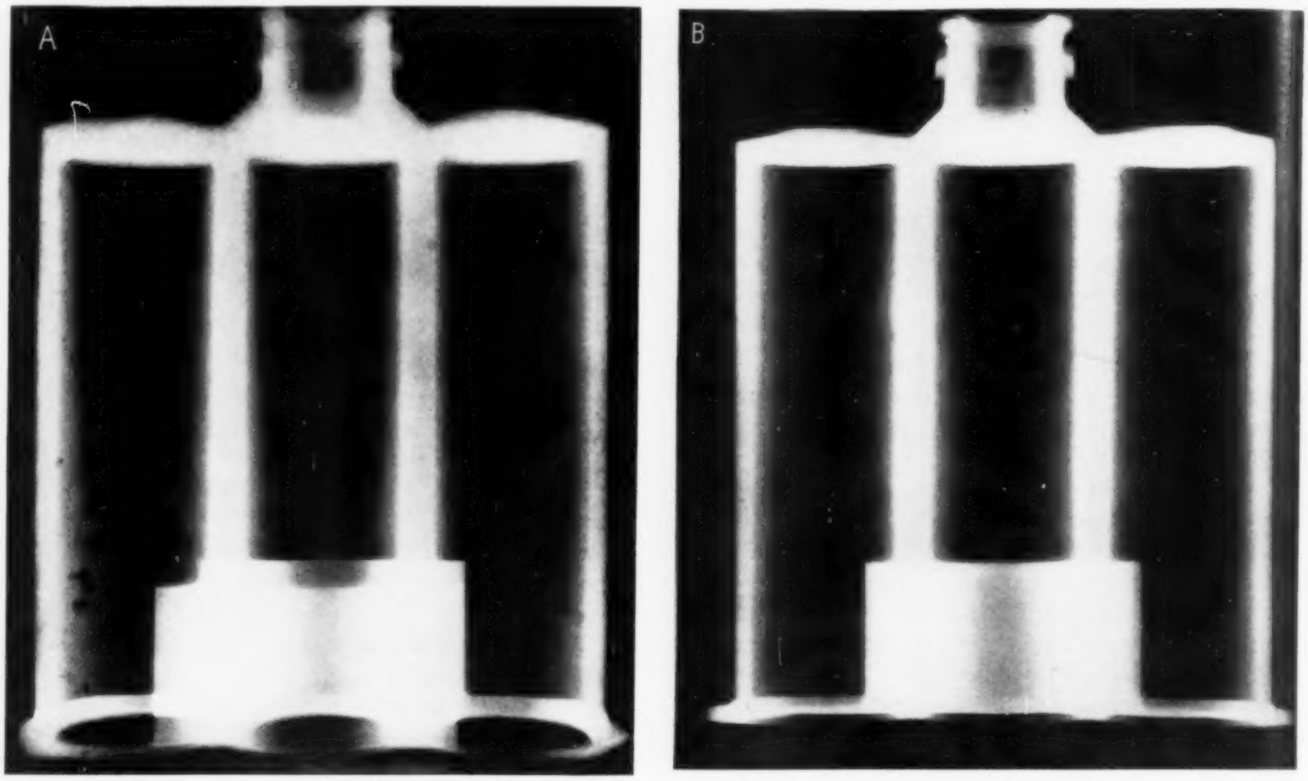
3. *Segregations,* such as copper, $CuAl_2$, iron, and other metallic inclusions of greater density than aluminum, will appear as well-defined light spots on mottled areas of any shape. Sand inclusions appear as an uneven granular texture with indistinct outline varying the density of the film. Sand inclusions are random in occurrence and usually tend to concentrate in or near the drag surface of the casting.

4. *Gas Porosity* is caused by hydrogen and appears on the film as spherical, round, or irregular dark spots. In coarse grained castings these spots tend to be elongated or curved. Porosity is generally distributed throughout the entire casting and the size of the hole varies with the gas content of the metal and the rate of solidification of the section in which it occurs.

5. *Microshrinkage* occurs in magnesium alloys and appears as very indistinct dark, feathery streaks on large areas. It is very general in occurrence; however, its presence indicates improper feeding.

Localized Types

1. *Cracks* — This type of defect appears as darkened lines of variable width. Cracks are dendritic when caused by hot-shortness. Cracks originating from residual stresses in solid metal are more linear or straight and of more constant width. Cracks are due to excessive strain or impact from outward forces, or to internal strains



Radiograph A Is of an Aluminum Casting — an Airplane Shock Absorber. As first run, the part contained damaging cavities in the tubular walls. After four changes in the method of gating the sand mold, checking castings radiographically after each change, the successful method was found for making sound castings shown in B. Engravings courtesy General Electric X-Ray Corp.

residual in the cast part, after removing from the mold or after heat treatment.

2. *Shrinkage* occurs as cavities, pipes, or shrinkage porosity. On the film it appears as dendritic dark regions of irregular dimensions and indistinct outline. Shrinkage porosity is a localized spongy area and results from the same cause as shrinkage. It appears as massive irregular darkened areas with indistinct outline.

3. *Cold Shuts* appear as darkened areas of variable lengths, usually with a smooth outline and a tendency to elongation and thin section. Their occurrence means that the metal entered the mold from two directions and failed to unite properly at the junction. In this category are also what are sometimes called "flow lines".

4. *Misruns* — This defect appears as a prominent darkened area on the film of variable dimensions with smooth outlines where the metal has failed to fill the section.

Acceptance Standards

It is highly important to note that these defects are divided into the two sections and that the general defects, such as blowholes, dross segregation, and gas porosity, are not nearly as serious as the localized types named which are directional.

It should also be emphasized that under no conditions should a partial opinion be formed as to the acceptability of a casting until all three of the factors mentioned at the outset have been thoroughly analyzed and taken into account. Each one has a distinct bearing on the acceptability of the part. Furthermore, no analysis will be justified without taking *each* one into full consideration.

It is appropriate at this point to mention the question of standardization of type and quantity of defects which are allowable in a casting. In the writer's opinion, it is highly impractical to attempt to standardize by defects. Thorough investigation of this subject, based on the experience of X-raying a large quantity of aircraft castings, has shown that the only type of practical standardization is one based on a standard pattern — that is, once the casting is presented for inspection, it is possible to standardize to some extent on the type and quantity of defect acceptable in that particular pattern for that certain use. However, this same standardization will have to be individually investigated before it is applied to any other pattern. This means that all standardization of this type of inspection can apply only to an individual casting pattern.

LIMITATIONS OF RADIOGRAPHY AS AN INSPECTION METHOD

BY VERNON I. E. WIEGAND
Radiographer
Wright Aeronautical Corp., Cincinnati

DUE to the limited time allotted each speaker at the Panel Discussions on War Production at the ⊕ Convention, it was necessary to brief the matter to the greatest possible extent. So the following outline, or check list, of the limitations or the proper and improper applications of radiography as an inspection method, is presented without apology for its literary form.

The subject of specific limitations has been subdivided into six main classes, each of which has further been broken up into its numerous factors.

Next are generalized, with explanatory remarks, the proper and the improper applications. Finally are listed a couple of dozen specific examples of proper applications, with special reference to the inspection of aircraft engine parts and sub-assemblies.

Specific Limitations

Characteristics of Part or Material to Be X-Rayed

1. Density of the Material: As the density of the material increases it becomes less permeable to X-rays and secondary radiation increases. This decreases the definition of the projected image.

2. Thickness of the Section X-Rayed may be beyond the range of ordinary equipment, requiring a special machine which might be uneconomical or unavailable.

3. Shape may be such that the X-rays could not penetrate into certain areas and reveal any defects present.

4. Degree of Thickness Variation: The difference in thickness of sections may be too great to give proper detail on one film, and require too many different exposures to be practical.

5. Size: If the part is too great or too small in size it might be uneconomical and impractical to X-ray it.

6. Position: If it is too difficult to position the part, due to its weight, or if it requires too elaborate fixtures to support it while being X-rayed to avoid superimposition of various areas, the inspection method may be impracticable.

7. Focal-Film Distance: The greater the focal-film distance the less the distortion and the better the detail of the image produced, but since the power of penetration varies inversely as the square of the distance, any increase in distance will greatly reduce the effective capacity of the X-ray generator.

8. Object-Film Distance: The greater the object-film distance the greater the distortion of the image and the less detail.

9. Condition of the Material: The previous treatment, such as heat treating, cleaning and machining, or cutting off beads of welds, may affect the proper interpretation of the X-ograph.

10. Quantity of Parts to be X-Rayed could be too few or too many, or the supply too irregular, periodically or numerically.

Characteristics of the Equipment

1. Capacity of the X-Ray Generator: Generators are built in several rated capacities and at this time there are none available that have a universal range applicable to all conditions.

2. Capacity of the X-Ray Tube depends on its type, such as whether the anode is stationary or rotating, or is air and water or oil-cooled, its insulation, and its construction to operate on certain voltage ranges; also on the size of its focal spot, and the type of rectification used in the high tension circuit.

3. Size of Focal Spot: The detail produced in an X-ograph is directly related to the size of the projected area of the focal spot. The smaller this area the finer the detail, but more limited the range of material that can be X-rayed.

4. Type and Intensity of Viewing Illumination: If illumination is not intense enough, or is fixed, or is not variable over sufficient range, required visibility is lacking on radiographs having higher densities and extreme contrast.

Characteristics of Discontinuity or Defect

1. Kind or Nature: If the defect is of such a kind or nature that there is little if any difference in density between it and the basic material very little information can be gained by making the X-ray picture.

2. Size: The defects may be so minute as to be undetectable by X-rays, even with the most favorable dimensions of focal spot in available equipment.

3. Location of Defect may prevent the X-ray beam from passing through it, because so large a proportion of the rays are absorbed by superimposed areas of the part, and prevent positioning of the part to avoid this condition. Any discontinuity whose plane is not parallel to the

X-ray beam would be harder to detect. It may also be located too far from the film to give good or sufficient detail.

Characteristics of the Film Emulsion

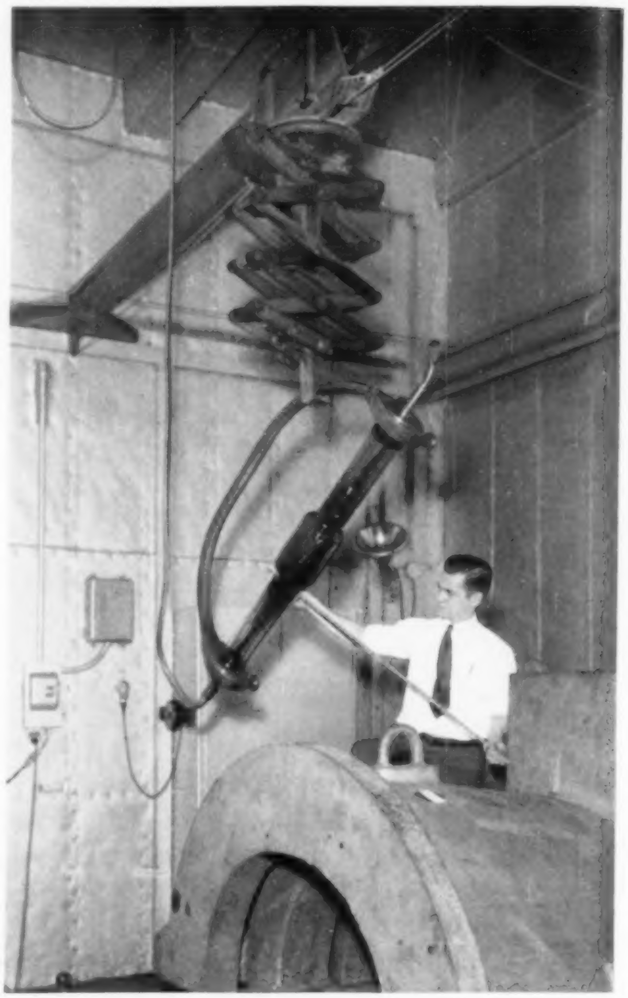
1. Contrast: Since this is a measure of the differences between the dark and light shadows on the finished radiograph it is very essential to use a film with an emulsion that will permit the production of the greatest difference necessary to detect the smallest discontinuities. In a film with great or high contrast the change from extreme white to extreme black shadows is accomplished much quicker and with less steps of difference between them than in a film having an emulsion with a greater number of steps, or a film having more "latitude". A film with a high contrast is desirable for X-raying a part or material of uniform thickness containing small defects, because they would show up more vividly and be more easily detected. In material with great thickness variation such a high contrast would be undesirable, because only certain areas would have the proper blackening, since the thicker sections would appear very white and the thinner sections very black. No detail would appear in these areas and small changes in thickness, such as small discontinuities, would therefore be invisible.

2. H & D Density (Film Blackening): This is a measure of the amount of transmitted light that can pass through the radiograph in any area. The greater the H & D density or blackness on the film, the less the transmitted light that can pass through it. High values of film blackening are generally used in X-raying materials made of lighter metals and alloys than are used with the heavier metals and alloys. The secondary radiation given off by the heavier metals makes it harder to produce higher contrast and film blackening; hence it is necessary in this case to use films with emulsions having as high a contrast as possible, or other means such as intensifying screens to enhance the contrast.

3. Speed of the film emulsion is measured by the amount of film blackening that can be obtained by a definite amount of X-ray intensity for a definite thickness of material. Using a film with too slow a speed could be a serious limitation.

4. Sensitivity of the Radiograph: Since this is the per cent ratio of the thickness of the smallest detectable defect to the thickness of the base material, and is controlled principally by contrast and definition or detail, it is essential to give consideration to the inherent contrast of the film emulsion.

5. Grain Size: Since definition or detail is controlled mainly by tube-target focal size, target-film distance, object-film distance and grain size of the film emulsion, it is necessary to choose a film with a fine-grain emulsion to aid in producing the greatest sensitivity for detecting the smallest or finest discontinuities. The finer-grained X-ray films are slower in speed, a matter which must be considered in selecting a film.



Suspension Mounting of 400,000-Volt X-Ray Tube in Lead Lined Room at General Electric's Schenectady Works, Being Adjusted for Radiographing a Large Steel Casting for a Turbine Case

Processing of Radiograph

1. Uncontrolled Temperature of Solution: Too low or too high a temperature may cause under or over-development of the film, chemical fog, or injury to the emulsion which would prevent standardization of the interpretational technique.

2. Too Old or Exhausted Solutions: This would cause improper development and fixation, and ruined detail, and hinder detection of small discontinuities. The film would also be stained.

3. Defective Cassettes, Artifacts, etc.: Imperfect contact between the film and the screen would cause poor detail on the radiograph. Arti-

facts on the film or in cassette may produce deceptive impressions on the processed radiograph.

4. Improper Handling of Film; Static, Pre-Fogging, etc.: Friction produced between film and black wrapping paper can cause static electrical discharges which cause images on the film resembling those produced by discontinuities like fine cracks. Sharp bending of the film may crack the emulsion, producing lighter areas on the film similar to defects of greater density. Pre-fogging of the film by either light rays or X-rays prevents clear detail, despite any change in exposure technique intended to offset those effects. Insufficient washing and inefficient drying may cause a lack of good detail in the finished film.

Proper Interpretation of the X-Ograph

1. Lack of Necessary Standard X-Ographs: Without X-ographs which represent the maximum permissible discontinuities of various known kinds, it is difficult to properly interpret subsequent X-ray pictures made of the same kind of material or similar parts. Failure to establish standard X-ographs therefore seriously limits the value of radiography as a method of inspection.

2. Insufficient Information to Correlate With the Reading of the Finished Film: The result of other physical or chemical analysis is very helpful in many instances when making the proper interpretation of the shadows on the X-ograph. Without these other results it is sometimes impossible to properly diagnose the condition from a view of the film alone.

3. Insufficient Number of Previous Films: The part may be of such kind and so few in number, or made of a new material or alloy, that the number of films made previously are an insufficient basis of comparison.

4. Differences in Interpretation: One limitation due to variation in opinion of different readers as to the importance or extent of defects is considerably overcome as the experience of the various readers widens or increases. Penetrameters or other tell-tale marks are also very helpful in obtaining agreement among interpreters.

5. Lack of Macroscopic Information: The presence of, or familiarity with, the object which was X-rayed is very desirable. Surface blemishes sometimes present very confusing shadows on the radiograph and these can be ruled out or discounted by observation of the object.

6. Improper Exposure or Dark Room Technique: The film may be over-exposed and under-developed or under-exposed and over-developed. In the former case, over-exposure causes loss of fine detail; in the latter case fine detail is lost or shows very faintly due to under-exposure. Any properly exposed negative can be ruined by improper dark room technique.

Proper Applications, in General

Quality Control on Foundry Practice

Considerable application has been made of radiography in the development of satisfactory casting or fabricating technique. Shrinkage, inclusions, and porosity have been eliminated, in large measure, by X-raying castings and determining where chills should be placed or removed, the best place to install gates and risers, or best position of mold for pouring. As a result of X-ray examination one of the major aircraft engine castings was considerably improved by inverting the mold, and pouring from the opposite side. After the technique has been developed satisfactorily, castings can be selected at random, or as specifically planned, from production lots to determine whether the approved method is functioning.

Inspection of Welds

The X-ray method is considered the most satisfactory and practical non-destructive way of inspecting welded joints in high pressure vessels. It is widely used in testing production welds of various structures, and in experimental development of welding procedures.

To Save Time and Expense of Needless Machining

Very often a discontinuity can be detected which may be located in an area across the face of a surface to be machined or in a place to be drilled or bored out. Considerable other expensive machining might have to be done before this area was reached in the machining operations and if the defect were only disclosed at that time all the previous machining would be wasted. While the saving of this machining expense may be considerable, in a critical period like the present the saving in time is the greatest consideration. Wasted time in a production schedule can seldom if ever be recovered.

To Check or Assist in Designing the Part

Sample parts are often designed, and cast or fabricated, and then X-rayed to determine quickly and efficiently if any defects exist in the internal structures. If the material is to be cast and defects *are* discovered they will usually duplicate themselves if no change is made in the foundry practice. If the defects still exist after such change, and if this is evident in subsequent X-ray examinations, then some changes in design of the part may be necessary.

Where Material Has a Very Important Use

Under this classification are material or parts used in aircraft construction, ordnance material of various kinds, structures supporting great weight or subject to high internal stresses and pressures.

Inspection of Material to Determine Effect of Time and Use

The X-ray has been used to determine the damage caused by decay of the wood at the ground line of utility poles. Also to inspect old reinforced concrete and welded structures in service.

Since oxide skin inclusions in magnesium alloys are extremely undesirable, because of their tendency to contain some flux which greatly accelerates corrosion, periodic X-ray examinations of these inclusions to determine if they had increased or grown during definite intervals of time, could be considered as another example of a proper application of X-ray as an inspection method.

Improper Applications

Where Other Tests Are Not Correlated

It is very important that the results of the X-ray examination are compared with other tests or data, such as heat treating, tensile bars, knowledge of pouring temperatures, chemical analysis, Brinell hardness, and so on. To arrive by mere X-ray examination at a conclusion on all conditions required for good quality would, in most cases, be an improper application of its use as an inspection tool.

Not Enough of a Percentage of One Heat to Form a Basis of Conclusion

If a large number of castings are poured on one heat and some change occurs in casting technique — such as wide variation of pouring temperature — it would be improper to X-ray a few castings and conclude that the whole heat was bad or good. It would also be improper to X-ray castings of a few heats only and none from other heats, since conditions are very apt to change.

Unimportant Use of Part or Material

Many parts have an unimportant use which would not justify inspection by X-ray.

Cost of X-Raying Too Great

The expense of X-raying might be too great in proportion to the value of the part or the cost of a failure. Or it would be improper to use X-ray when some other method, such as black light or magnaflux, might be used more easily or efficiently.

Where X-Ray Does Not Apply

Quite often requests are made to use the X-ray to determine the effects of stresses on the internal structures of parts after use. Often only one part may be available for this purpose, when the conditions might be such that it would require a series of X-ray examinations of many of the same kind of parts, operating under similar conditions, to be able to form the basis of a conclusion as to the value of the evidence obtained in that manner.

Specific Examples of Proper Applications

The Inspection of Finished Products

Such as electrical assemblies, heating units, fuses, and vacuum tubes to check for *(a)* position or alignment of parts, *(b)* continuity of circuits and *(c)* possible short circuits.

Mechanical assemblies, to detect added parts in hidden locations, such as broken-off drill tips.

Electrical cables, to check uniformity of insulation, and concentricity of conductors, insulation and sheathing.

Spark plugs, rubber tires, and golf balls.

Ordnance parts such as fixed rounds of explosives, shells, fuses, and caps.

Inspection of Joints

Welded, soldered, glued, brazed joints, and shrink fits in assemblies, to check for *(a)* location of the fusion, *(b)* presence or absence of surplus fusion material, *(c)* glue pattern in plywood and *(d)* shrinkage, poor bond, and other discontinuities in steel-backed bearings.

Locating Position of Metal Inserts

In molded material such as plastics and ceramics in electrical plugs, distributor caps, sockets, insulator bushings.

Measuring Concealed Objects

1. Inside diameter of pipes.
2. Inside thread sizes.
3. Fit of threaded hole and screw.
4. Sodium content of exhaust valves.
5. Size and locations of inclusions in castings.

Determining Location and Size of Concealed Structures

1. Plumbing pipes and electrical conduits.
2. Joists and columns.
3. Steel reinforcement in concrete.
4. Internal structure of archeological objects.
5. Condition of wooden utility poles at the ground line.

Determining Kind of Materials and Their Distribution

1. Identifying lead segregates and carbon inclusion in bearings.
2. Thickness variations in bearings.
3. Elimination of silver-impregnated carbon contacts which have unevenly distributed silver.
4. Shrinkage of material in castings.
5. Identifying forged and cast materials in finished parts; for example, cam rings in aircraft engines.
6. Porosity in castings and bearings.
7. Differentiating between natural and artificial stones and pearls.
8. Age of old oil paintings.

NEW DEVELOPMENTS IN EQUIPMENT, FILMS AND TECHNIQUE

BY L. W. BALL
National Research Laboratories of Canada
Ottawa, Canada

THE NEW DEVELOPMENTS in equipment, films and technique that shall be catalogued for you are not academic pipe dreams; they are all highly practicable and their value has been proven in work geared to rapid mass production.

We may list five major developments in equipment.

First, the source of our radiation has been developed. Bulky X-ray tubes and radium capsules designed for cancer therapy have been replaced by fine-focus X-ray tubes and highly condensed radium capsules that have been specially designed for high quality industrial work. Radiation coming from outside the focal spot has been reduced by better focusing of the electron beam inside the tube. In some cases radiographic definition has been improved by eliminating insulating oil from the path of the primary X-ray beam.

Second, the fogging of radiographs by radiation scattered by the film holder has been analyzed, and cassettes have been designed which eliminate it completely. Similar fogging due to X-rays scattered by other material in our X-ray cabinets has been analyzed, and it has been shown that this also can be eliminated by the use of proper stops and a heavy metal sheet placed immediately behind the film.

Third, to handle the tens of thousands of parts that now pass through our larger testing laboratories, automatic equipment has been developed to do most of the exposure operations previously performed by technicians. Electronic controls for the automatic setting and accurate repetition of the tube current and voltage have been built into this equipment.

Fourth, misleading markings, that are frequently produced on radiographs by the traditional methods of dark room processing, have been eliminated in the design of completely automatic processing machines. These machines speed up production by handling 500 films per hr. Their use reduces both the number and the training of men required in the darkroom.

Fifth, the use of 200-kilovolt X-ray equipment for testing irregularly shaped steel objects by mass production methods was beset with almost insuperable difficulties. This unsatisfactory condition has been eliminated by the advent of much higher voltages. It is true that the 1,000,000-volt X-ray equipment is a very important development because it can penetrate quickly 4 in. of steel, but it is just as important because it allows reliable mass production inspection of much thinner but irregularly shaped objects.

So much for apparatus. Film manufacturers have kept pace with the other developments, and they have given us several new types of film that are specifically designed for industrial problems. One of these has cut the duration of radium exposures many times over. This particular type is coarse grained, but it is suitable for showing the gross defects that radium reveals so clearly. New fine-grained films have been developed to satisfy our demand for fine resolution of conditions such as microshrinkage in magnesium. They give as clear a picture of a crack 0.001 in. wide as was previously obtained for a crack ten times as wide. It is these fine-grained films that are best suited for most X-ray work. However, war production includes complicated castings whose shape prevents work of very high sensitivities, and for these parts such fine results cannot be attained so another type of film is available. It has moderate grain size with sufficient speed to allow the use of the necessary heavy lead filter.

Other developments in films include the use of a thin base to reduce parallax, and of green tinted films that take advantage of the eye's greatest sensitivity to contrast. An enormous increase in film contrast has resulted from the use of high film densities and extremely intense viewing lamps. In the case of radium radiography, the high film contrast obtained at high film densities can compensate for low subject contrast, and so small metal thicknesses can be successfully inspected with radium.

Developments in Technique

Technique is a big subject, but I will try to pick out just the highlights. Technique includes the choice of proper voltage, exposure, type of cassette, type of film, and of the orientations and the source-film distances that will give the most reliable, the most economical, and the most rapid inspection of a given radiographic subject.

For material of uniform section this is a rather simple matter, and fortunately a penetrameter placed on top of a uniform section provides a satisfactory measurement of the reliability of the technique that is decided upon.

A vitally important development has been the recognition that the reliable inspection of complex objects, such as steel castings for tanks and light alloy castings for aircraft, bears very little relation

to the traditional inspection of uniform sections, and that reliance on penetrameters of the common type is extremely dangerous.

This last sentence is so important that it bears re-reading, so it will be repeated:

A vitally important development has been the recognition that the reliable inspection of complex objects, such as steel castings for tanks and light alloy castings for aircraft, bears very little relation to the traditional inspection of uniform sections, and that reliance on penetrameters of the common type is extremely dangerous.

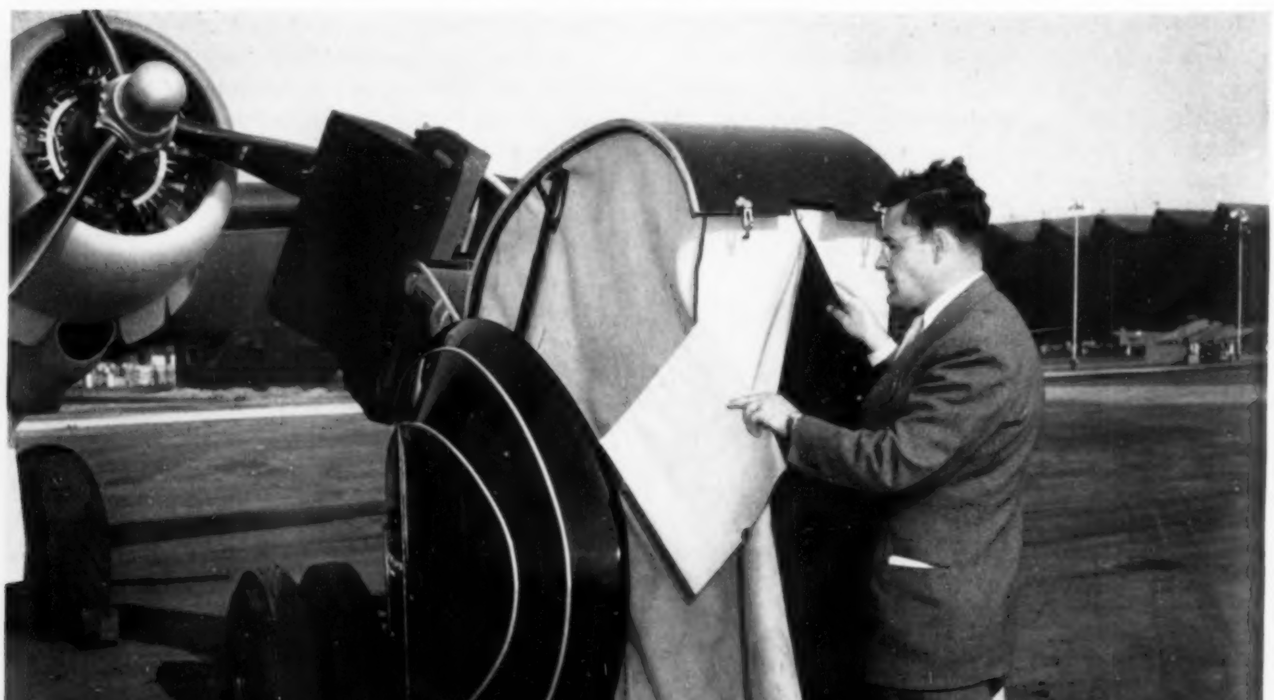
Fortunately, the factors that affect the sensitivity attained in the radiography of complex shapes have been fairly well analyzed, and almost any article in our war production can be radiographed fairly well.

The switch from civilian to war production has greatly increased the number of manufacturing problems to which radiography has been successfully applied. This has led to one important development that does not quite fit into my title. It is the development of X-ray laboratories from button-pushing side lines to a vital link in the organization of many of our industries. Efficient war production requires that the services of competent radiographers be made available to every foundry and forge shop.

A very recent development has been the approval of a standard terminology for industrial radiography by the American Society for Testing Materials and the American Foundrymen's Association. This will make for better understanding between all those engaged in this work and it will help to clarify discussions of radiographic technique, interpretation and procedure.

Radiography has not been idle in advancing to meet our war responsibilities. If we have done less by radiography for our equipment than has undoubtedly been done by our enemies, it is because many old-fashioned industries have been too slow to use it. It is a powerful inspection tool, and we radiographers ask the manufacturers to let us help finish the job the Japs started.

Portable X-Ray Equipment Includes a Truck Carrying Electrical Generator (Not Shown in This View) and "Tear Drop" Trailer Carrying Tube and Its Mounting. Body of trailer forms a dark room in which films can be developed and inspected on the job. This equipment saves the trouble of dismounting suspected parts, sending them to a laboratory, and remounting them if they prove to be sound. Photo courtesy Triplett & Barton

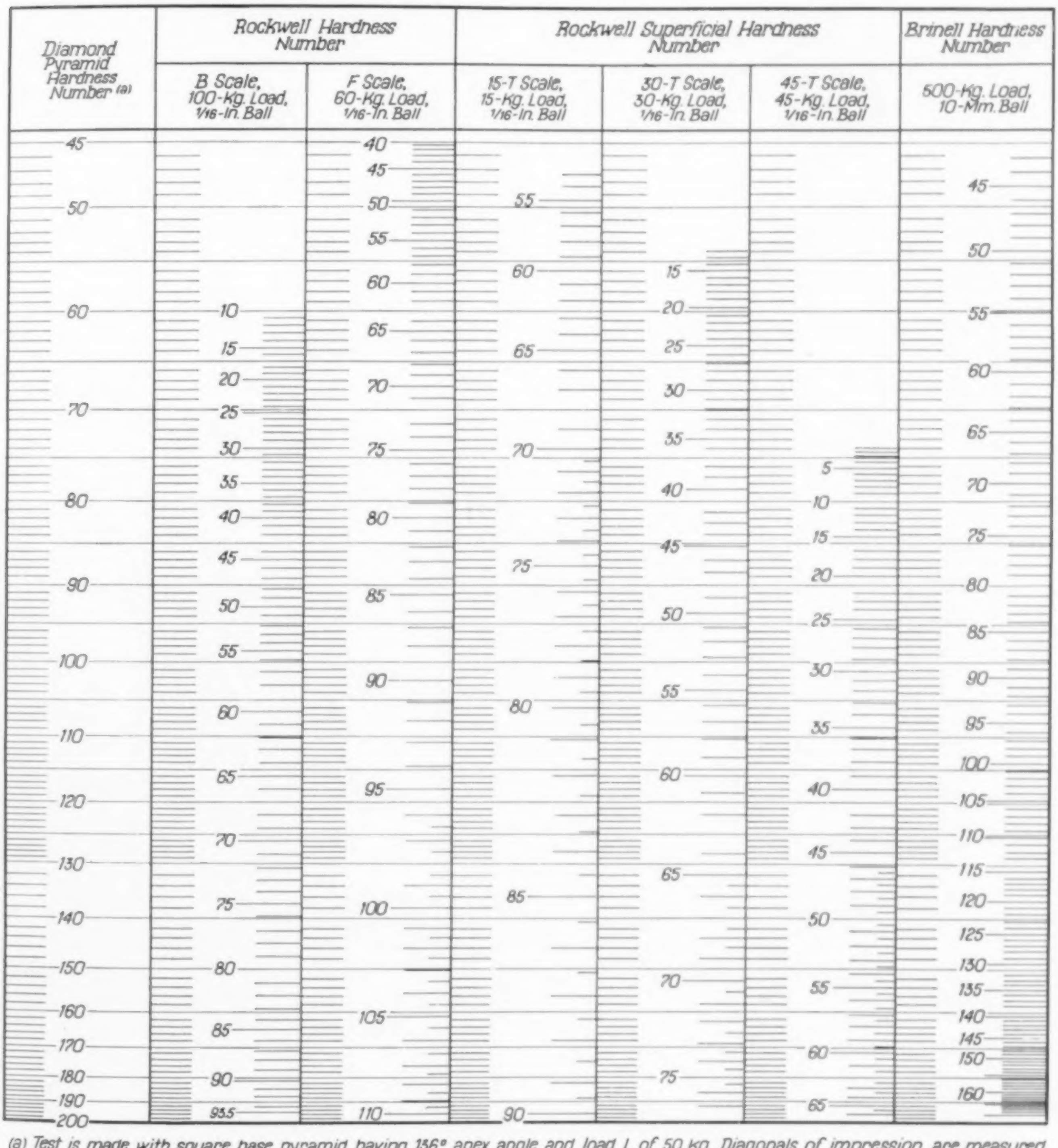


Hardness Conversion for Cartridge Brass

(70% copper, 30% zinc)

Preliminary Report of A.S.T.M. Committee on Indentation Hardness

Comparative values hold only when standard test procedures are followed, and only when made on flat specimens of cartridge brass thick enough to avoid the anvil effect (roughly 10 times the depth of the indentation).



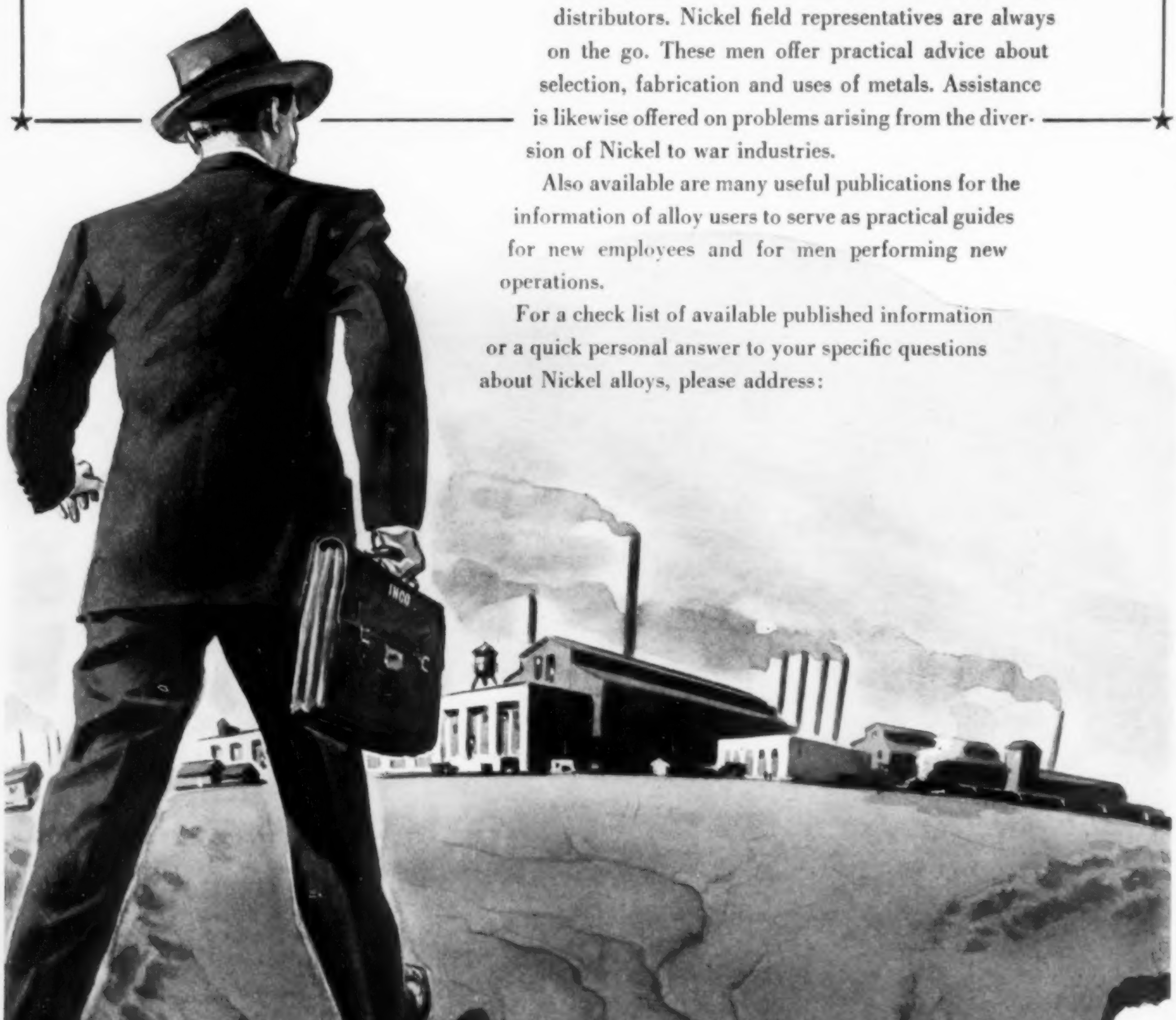
(a) Test is made with square base pyramid having 136° apex angle and load L of 50 kg. Diagonals of impression are measured in mm. and averaged as d. Hardness number $= \frac{2L \sin 68°}{d^2}$

ON THE MARCH to aid users of alloys...

FIELD offices are maintained by International Nickel's Development and Research Division and by qualified distributors. Nickel field representatives are always on the go. These men offer practical advice about selection, fabrication and uses of metals. Assistance is likewise offered on problems arising from the diversion of Nickel to war industries.

Also available are many useful publications for the information of alloy users to serve as practical guides for new employees and for men performing new operations.

For a check list of available published information or a quick personal answer to your specific questions about Nickel alloys, please address:



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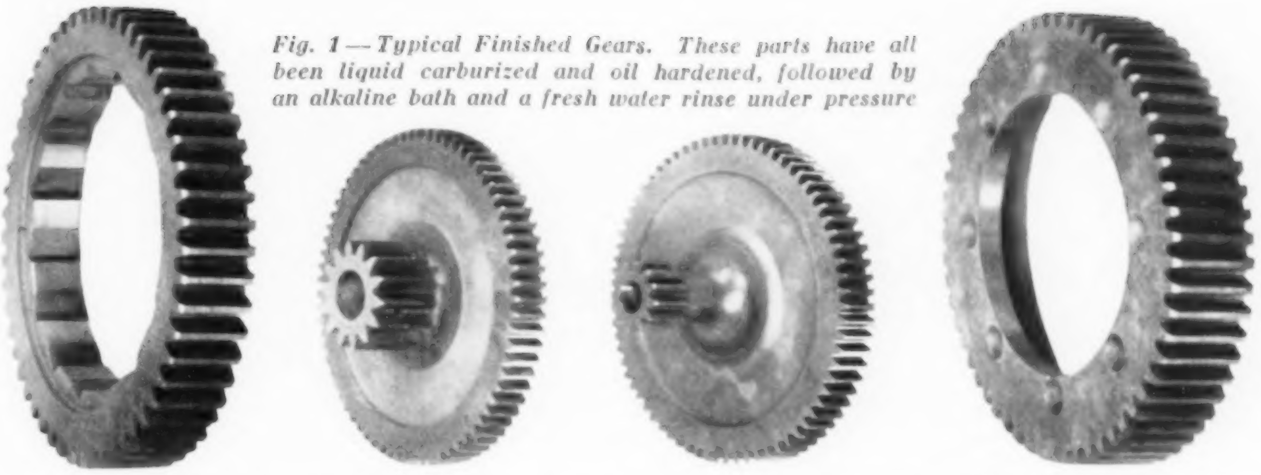


Fig. 1 — Typical Finished Gears. These parts have all been liquid carburized and oil hardened, followed by an alkaline bath and a fresh water rinse under pressure

CARBURIZING GEARS IN THE ELECTRIC SALT BATH FURNACE

BY WILLIAM F. SORENSON
Metallurgist, Yale & Towne Mfg. Co., Philadelphia

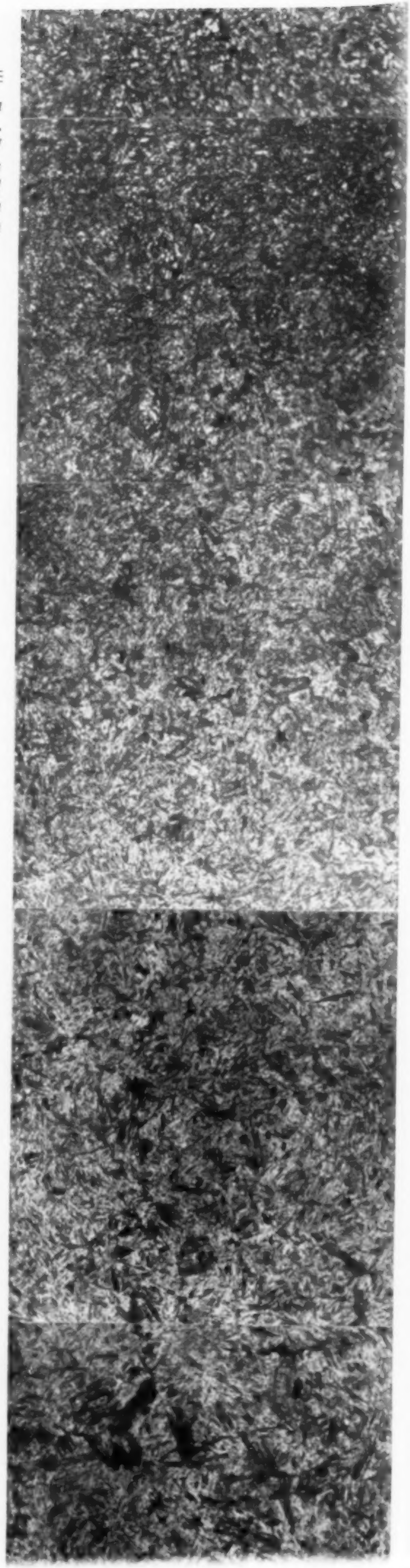
THERE is an ingrained American habit of insisting that quality control must keep up with quantity output, no matter how high that output may go. Perhaps this is no more evident than in the production of gears, and this paper will deal chiefly with metallurgical control coordinated with production in the heat treatment of oil hardened gears and axles, as well as carburized gears and parts, during the recent period when output multiplied many times over, with no end in sight.

In the manufacture of Yale & Towne hand lift and electric trucks and industrial hoisting equipment, there are many types and sizes of gears, including high-speed and low-speed gears, intermediates, differentials, spur, pinion, and driving gears. They may be of from 4 to 8 pitch and diameters of 6 in. or less up to 12 in. The steels include S.A.E. 3140, 4150, 5140, and the new NE8949 (oil hardening chromium-nickel-molybdenum). These steels are all heated at various appropriate temperatures from 1450 to 1525° F. in electric salt bath furnaces. Carburizing steels, also treated in the salt bath furnace, include S.A.E. 4615, 4815, X-1315, and the NE carburizing steels. Typical gears of this sort are shown in Fig. 1.

Quality control of carburized gears assumes properly normalized and annealed gear blanks. As Sauveur observed, "The annealing process has an important bearing on the physical properties, mechanical treatment, and the subsequent effect of the heat treatment of steel after machining." If there is an incorrect structure to begin with, there will be stresses and strains after hardening which even prolonged drawing will not remove. Given the correct structure, however, quality control naturally revolves about the physical properties, degree of distortion, and final finish.

The gears under discussion are given a mirror finish in a special operation prior to heat treatment, in which as much as 0.002 in. may be removed from one side of a single gear tooth. In order to avoid oxidation, the necessity for sand blasting, or distortion after heat treatment, the liquid carburizing method is preferred. A furnace of the immersed electrode (Ajax-Hultgren standard 65-kw. size with roller-type cover) was

Fig. 2 — Section of Oil Hardened, Carburized Gear Tooth With a Case of 0.030 In., Showing Typical Martensitic Structure of Case. Magnification 400 diameters. Hardened case is wholly free of deoxidation or decarburization. The transition structure begins with the light-colored area at about the middle, progressing inward to the full core structure, as shown at the bottom. A total depth of 0.090 in. is covered by this continuous photomicrograph



installed two years ago. Its operation 24 hr. a day discloses much of interest, as will be seen.

The time for a carburizing cycle is much reduced when liquid bath is substituted for the older pack carburizing, especially when it is recalled that after packing the parts in carburizing material, 4 to 7 hr. may be necessary to bring the pots up to heat, depending upon the type of parts and the size of the charges. It is apparent that parts are brought up to heat much more rapidly and evenly when immersed in molten cyanide salts; on the average, the total heat treating time has been sharply reduced as compared with gas, while, after oil quenching, the mirror-like finish is retained, free of oxidation or scale. These comparisons are made because virtually all types and methods of carburizing have been utilized, at one time or another, in this department. Rockwell hardness of C-58 to 62 is required on carburized gears, and the case depth normally called for in the liquid bath is approximately 0.030 in. The total immersion and withdrawal cycle for this case is about 3 hr. in the liquid bath. Greater case depths (up to 0.125 in.) may be produced if time and temperature are provided. Distortion in the liquid bath is held to a minimum 0.0003 in. at spacing on the pitch line of the gears; involute profile distortion rarely averages more than 0.0004 in., with frequent zero distortion at the crown.

In addition to gears, most of the tilt handle shafts, steering knuckle pins, bolts, bushings, and axles are liquid carburized. Axles range from 6 to 36 in. in length, and from 1 to 2½ in. in diameter. Some of these are given cases of 0.050 in. (more if called for in special, infrequent designs). Axle steels include S.A.E. X-1315, 4615, 4815, and 2515 for hand trucks. Gas carburizing equipment is available if an exceptional depth of case is specified but all such parts are cooled in protective atmosphere and reheated in the liquid bath for quenching, to prevent both oxidation and decarburization. (Parts carburized in the liquid bath to begin with are oil quenched directly.) Since the bath is maintained in balance and tested every day for correct cyanide content required for carburizing use, reheating gas-carburized articles in such a salt bath will inevitably prevent decarburization at the surface under all conditions of production.

Cases deeper than 0.050 in. are also produced on certain parts with a Rockwell of C-58 to 62 in the gas furnace, but there is likelihood of embrittlement since it is always difficult to maintain no more than normal eutectoid carbon together with a margin of elasticity in the case itself.

A typical oil hardened, carburized gear section is shown in Fig. 2, with martensitic structure, total absence of decarburization or oxidation, and the characteristic strong and ductile core. This gear, of S.A.E. 4615 steel, was

annealed and normalized, then machined, and carburized for 3 hr. in the liquid bath at 1650° F., followed by an oil quench. Introduction of more carbon would cause excess carbon to segregate in the form of free cementite at the grain boundaries, giving a more brittle case. It is, of course, good practice to hold to a normal 0.90% carbon as a maximum, or even less if necessary to avoid the hyper-eutectoid case.

The problem of distortion also increases with higher carbon, as it does with the thicker cases; in shafting, straightening difficulties also appear because the case cracks readily. In fact, it is observed that liquid carburized cases do have a slight and desirable elasticity, whereas in a gas carburized case there appears to be none whatever. For example, a recent but representative test was made on tensile test pieces of S.A.E. X-1315 steel, one carburized in liquid bath for 3 hr. 20 min., the other in gas for 9 hr. Both pieces had case depth of 0.032 in. and hardened to C-62. Loads as measured on the beam were as follows:

	Liquid Carburized	Gas Carburized
Yield	21,000 lb.	24,980 lb.
Ultimate	22,000 lb.	24,980 lb.
Elongation	0.5%	0.0%

Our electric salt bath furnace has a working bath area of $42 \times 20 \times 18$ in., exclusive of the area devoted to the two pairs of closely spaced electrodes. This working area accommodates as many as 20 gears, 12 in. diameter, or the equivalent weight of metal in smaller gears or parts in a single charge.

Large gears are suspended on hooks, or hung from one or more wires. Occasionally, two small gears may be placed back to back on the same hook. They are lifted out one at a time, and lowered in the oil tank. During the quench, gears are deeply immersed, and carefully swung back and forth. The bath is equipped with a Niagara liquid cooling system which keeps oil temperature below 140° F. Maintaining a suitable core structure requires this procedure. Because of virtually continuous operation, the temperature of the quenching oil rarely falls below 100° F.

Depth of the molten activated cyanide salt is maintained at 18 in., and the furnace holds 1600 lb. of it when filled to this working level. An activated carburizing salt is maintained in balance by adding 75 lb. per 24 hr. during varied and heavy production. Weight of steel in a single charge will vary somewhat, but the average is about 250 lb. of gears or other parts. Larger charges may be handled successfully because the salt bath is a heating medium rather than a heat storage medium, and the speed with which metal itself will absorb heat and come to temperature is the sole limiting factor in determining power input and the thermal balance. Moreover, it may be observed that the chief reason for the exceedingly small distortion in the work appears to be attributable to the uniformity of bath temperature which causes the steel to be brought uniformly through the critical range to hardening temperature.

Close Control of Temperature

For example, usual carburizing temperatures vary from 1550 to 1650° F. and control is within 5° at all times. Equalization of temperature throughout the bath and in sections of parts of varying mass and area is within the limits of error of the pyrometric equipment. Gear teeth themselves, representing relatively thin sections, might be expected to heat more rapidly than the mass of

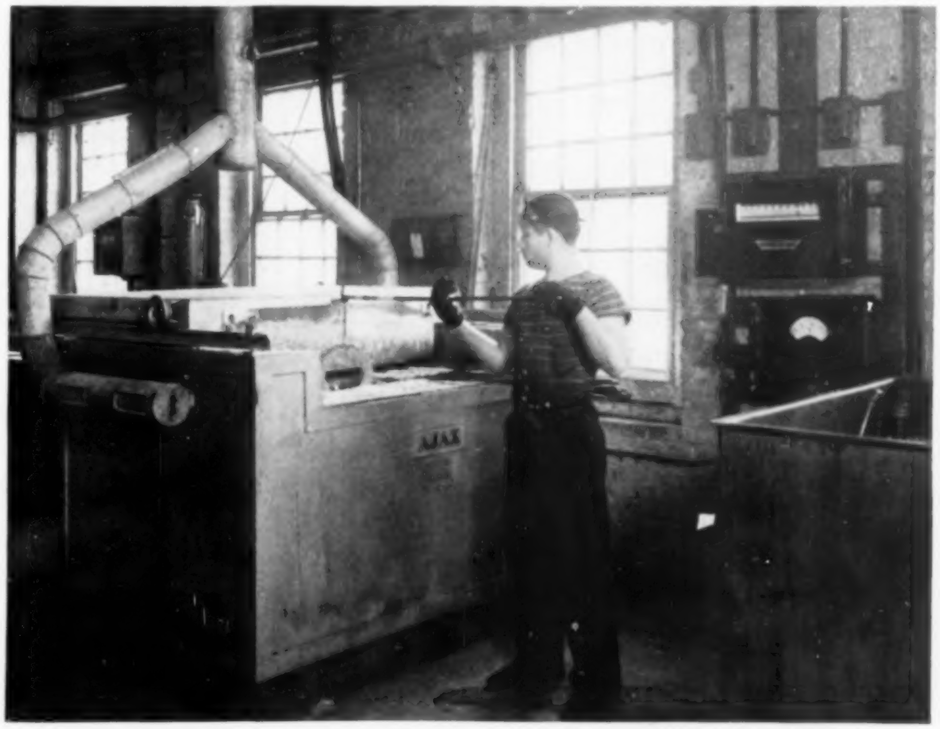


Fig. 3 — Electric Salt Bath Furnace in Heat Treating Department of Yale & Towne Mfg. Co. Operator is removing a carburized ring gear, ready for quenching in the tank at the right

metal at the root. But this would result in distortion were it not for uniform heating by conduction at all points. This is especially noteworthy in fairly large and massive, heavily carburized gears, which may have teeth measuring 0.5 in. from outside to root diameter.

The factors of precise control of temperature, elimination of sand-blasting (which does roughen the parts), and lowered distortion, would all seem to represent something inherent or characteristic of the furnaces described. Were it possible to place a proper premium on time savings, in view of the importance of this factor today we might make spectacular comparisons between the 7-hr. heating period plus the 3-hr. carburizing time in compound, and the overall 3-hr. period required for the same case depth with the same weight of charge in a liquid carburizer.

Our salt bath idles fewer than 4 hr. out of the 24; the stand-by temperature is kept at 1180° F., above the freezing point of the salt. Furnace maintenance is low, and working conditions are ideal because there is no excessive heat radiation, no obnoxious fume, and no explosion hazard.

After the oil quench, gears and parts are all given an alkaline cleansing bath, followed by a fresh water rinse, under pressure. Gears taken from the bath show much of the original high polish; when held up to the light, there is only the wavy pattern or slight mottling to indicate they have been heat treated at all. See Fig. 4.

Hardened gears are packed in baskets, close together but without touching, and drawn in an air convection furnace at temperatures varying from 400° F. to 850° or 900°, depending upon the type of gear and steel.

Gears are methodically checked for distortion and spacing on the center line, using Illinois involute testing machines and standard Yale & Towne equipment. As noted in the representative table, warping tests for differential gears disclose unusually low deviations. On a high-speed gear made of S.A.E. 4615, typical involute profile readings may show 0.0004 in. deviation from absolute position prior to heat treating, and 0.0008 in. after hardening. This fractional variation attributable to distortion is typical of the salt bath process as described.

Similarly, spacing on the pitch line shows a maximum distortion of 0.0003 in. after heat treating in the liquid bath (readings taken before and after hardening on 70 teeth and averaged). Likewise, the eccentricity measurement shows gears entering at a deviation from the absolute of 0.001 in. and leaving the bath at 0.001 in. In this connection, it may be emphasized that to hold deviation on gears to within 0.0005 in. at any time presupposes both limits and standards of practice which are quite uncommon and exceedingly high and exacting. Crown measurements indicate zero change after heat treating with gratifying regularity, readings being 0.0007 in. prior to heat treating, and 0.0007 in. after the entire process has been carried through. (This test was taken with the comparatively large 8-pitch gear.)

This is not perfection, however hard it might be to match it, yet at the same time, it is scarcely to be achieved on high production except in the best furnaces and procedures.

Fig. 4 — Carburized and Oil Hardened Gear Tooth, Showing Slight Mottling. Unstained view shows the same gear tooth prior to heat treatment. Enlarged 4 diameters

Measurements in 0.0001 In. on Typical High-Speed Gears of S.A.E. 4615, Before and After Hardening

	"A" Gear		"B" Gear	
	Before	After	Before	After
Involute profile,				
Tooth A, right side	–4	–8	–3	–6
B	–4	–9	–2	–7
C	–4	–8	–3	–6
D	–4	–7	–3	–7
Tooth A, left side	–3	–6	+2	–6
B	–3	–5	+1	–6
C	–4	–7	+2	–6
D	+1	–4	+1	–5
Spacing on pitch line, 70 teeth, all measured				
Maximum deviation from correct	0	0	+1	+3
Minimum deviation from correct	–1	–7	–1	–3
Maximum, tooth to tooth	1	3	1	4
Eccentricity	10	10	8	5
Crown	5	5	4	4

FOREIGN CORRESPONDENCE

(AND A GHOST)

LIMIT NITROGEN IN "STABILIZED" STAINLESS

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

Some interesting studies by William Hume-Rothery and his colleagues at Oxford University have shown that the colored non-metallic inclusions, so characteristic a feature of the microstructure of steels containing titanium, consist of a solid solution of titanium nitride and carbide, the former predominating. These investigations were carried out on steels sensibly free from any alloying metals except titanium, but one may perhaps apply the results to others of a more complex character and some interesting practical considerations then arise.

Titanium is frequently added — as is well known — to austenitic chromium-nickel stainless steels, in order to remove or reduce the tendency they would otherwise possess to undergo intergranular corrosion after they have been heated at a dull red heat. It is also well known that the beneficial effect of titanium results from the fact that it combines preferentially with the carbon in the steel, and thereby prevents the formation of chromium carbide at the grain boundaries — and hence the simultaneous production of the chromium-depleted bands which are the immediate cause of intergranular susceptibility — when the steel is heated within the dangerous range.

It is probable that all austenitic stainless steels, whether titanium be added to them or not, normally contain small amounts of nitrogen, possibly something of the order of 0.03%; indeed it was claimed by H. H. Uhlig in his paper before the ⊕ Convention in 1941 entitled "The Role of Nitrogen in 18-8 Stainless Steel" that if these small amounts of nitrogen were not present, 18-8 steels, with the normal carbon content of 0.10% or thereabouts, would be partly ferritic instead of wholly austenitic. There is at least no doubt that when these steels contain titanium, the characteristic colored inclusions — similar in appearance to those studied by Dr. Hume-Rothery which have been shown to consist mainly of titanium nitride — are present in their microstructure.

These "nitride" inclusions will obviously absorb a certain amount of the added titanium, but if the nitrogen content be not higher than about 0.03%, the amount of titanium thus rendered inoperative for combining with carbon will not exceed about 0.10%, and will be covered by the small excess of this metal above that theoretically required to combine with all the carbon in the steel — an excess which is normally added to the latter as a matter of safety.

During recent years, however, there has been a tendency to introduce nitrogen into corrosion resistant steels in amounts up to about one per cent of their chromium content. This practice has been more common in the melting of high chromium ferritic irons, but the addition of nitrogen to the austenitic chromium-nickel steels has also been suggested as a means of increasing the stability of the austenite, of economizing in nickel, or of improving certain mechanical properties.

So far as I am aware, these suggestions have been made in connection with austenitic steels which did not contain titanium, but if the results with such steels appear to be worth while, the scope of the nitrogen additions may be extended. What effects, therefore, may be anticipated if such amounts of nitrogen are purposely added to, or are accidentally present in, austenitic steels which have been dosed with titanium to prevent the occurrence of intergranular corrosion?

It seems probable that in such circumstances the greater part, if not the whole, of the nitrogen will combine with titanium to form the characteristic colored nitride inclusions and, if so, at least three disadvantages will arise. In the first place, the nitrogen will not be able to exercise any stabilizing effect on the austenite; secondly, the amount of non-metallic inclusions in the steel will increase appreciably; and thirdly, a considerable fraction of the added titanium will be rendered ineffective

for the purpose for which it is added, namely the prevention of intergranular corrosion.

The extent of the last named action may be gaged by the fact that the atomic weights of carbon and nitrogen do not differ greatly and the compounds they form with titanium have similar formulas; in other words, the effect of nitrogen in this respect would be broadly the same as that produced by raising the carbon content by a like amount.

It would seem advisable, therefore, to limit the nitrogen content of titanium-treated steels to as low a value as is practicable. As drugs for freeing steels from certain ills, nitrogen and titanium have each their own spheres of usefulness, but they are incompatible. (Incidentally, as columbium, tantalum and zirconium behave like titanium in forming stable nitrides, it is quite possible that similar remarks apply also to these metals and to steels to which they have been added.)

J. H. G. MONYPENNY
Metallurgist
Brown, Bayley's Steel Works, Ltd.

EXPLOSIONS OF GAS CYLINDERS CONTAINING AUTOMOBILE FUEL

SOMEWHERE IN FRANCE

To the Readers of METAL PROGRESS:

The scarcity of gasoline for motor car engines has directed attention to substitute combustibles, particularly of the gaseous type such as producer gas, water gas, and illuminating gas.

For this purpose illuminating gas is now stored under pressure in steel cylinders similar to the other compressed gases which have been long used for other purposes — namely, oxygen, hydrogen, carbonic acid, and others. High pressures in bottles made of high strength steels carry the largest possible quantity of gas in relation to the weight of the container. In general, pressures of 3000 to 3500 psi. are used. Cylinders are made either of plain carbon steel or of a special heat treated steel with thin walls.

While this use of compressed illuminating gas for automobiles became general in Germany, then in France, it was accompanied by many explosions either in charging or transport.

Observations in Germany indicate that these gas cylinders often show a type of cracking corrosion which has not been found in cylinders for oxygen, hydrogen, CO_2, and methane. These accidents did not begin immediately, but after several years of use. Fissures have been found oftener in light-weight cylinders made of special steel than in the heavy cylinders made of plain steel; the latter have been involved in far fewer accidents. The fissures become sharp and show up on developing the surface of rings cut from the cylinders; they contain substances which can be identified as derivatives of hydrocyanic acid.

In France, also, examination of cylinders which contained illuminating gas, particularly cylinders that had exploded, showed the presence of corrosion cracks branching off into the metal to depths about half the thickness of the walls.

Phenomena of corrosion cracking, therefore, seem undoubtedly to be present. The principal factor is the nature of the gas and not of the metal, since these explosions and fissures have not been found with other gases. The greater frequency of failure noted for cylinders of special steel might be attributed to the decreased thickness of the walls and the consequent higher rate of penetration into the metal. Speed of corrosion-cracking increases, in fact, with the strain existing in the metal and the influence of a deep fissure on the strength of the walls is naturally greater when the walls are thinner.

The corrosive agent which causes these failures should be sought in the gummy condensation products of the illuminating gas, which may contain hydrocyanic acid, organic oxides such as formic acid, or sulphurous compounds. It is thus related to the degree of purification of the gas, and this explains the fact that accidents and fissures have not occurred with the same frequency in various regions and different countries.

To remedy the difficulty recourse might be had to protecting the interior of the walls of the cylinders by a special coating or lacquer, or to the use of the so-called non-corrodible steels. However, it is much simpler to purify the gas, especially by condensing as perfectly as possible the products decomposing in the cylinders, refrigerating the gas and then charging it into the cylinders.

ALBERT M. PORTEVIN

EDITOR'S NOTE—Sometime before the German invasion of Southern (Vichy) France, M. Portevin mailed a few letters to this department, and they will be published in subsequent issues.

HEAT TREATMENT OF SMALL GUN BARRELS

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

Heat treatment of gun barrels for infantry rifles and machine guns is an interesting subject at the present time, and in England, at least, depends to a considerable extent on the stresses set up by the "proof round" of ammunition used by the Small Arms Inspection Department in the acceptance test. The steel should give a yield of not less than 58,500 psi. when tested to British

Standards Institution Specification No. 18. If the steel passes this test then it will successfully withstand the pressure raised by the "proof round".

Service rifle barrels in Britain have been made for many years from a straight carbon steel with the following analysis: Carbon 0.50 to 0.60%, silicon 0.25%, manganese 0.50 to 0.70%, sulphur and phosphorus 0.030% max. each. If the barrel is made from a rolled bar (upset at the end to make the form necessary to fix to the rifle body and to thicken up the barrel at the breech end where the highest pressures take place) the rolled bar is first cut to length and then heated at one end to 2000° F. to be upset in a forging machine.

Great care must be taken that the forging temperature is not too high, otherwise there is a danger of the steel being burnt. If the forging temperature is too low, then the steel will not be plastic enough for proper forging. Due to the forging and the work performed on the end of the bar, the structure of the bar is not constant along its length, the grain size being coarse at the end which has been upset. Therefore a normalizing treatment has to be carried out.

Normalizing is also necessary to get the steel into a suitable condition for machining. In the delicate operations such as boring, reaming and rifling, machinability of the bars should be constant from end to end, as any change in the structure in the length of the bar will adversely affect the tools and often mean a waste barrel.

Normalizing may be done either in an electric, gas or oil furnace, which may be vertical or horizontal. If it is vertical, the bars can be hung from a carrier and suspended in the furnace. If the furnace is horizontal the bars must be supported on cradles, trays or other fixtures. Normalizing temperature for the steel in question is 1560 to 1580° F., and the bars must be well soaked. Time depends largely on the bulk of material and the size of the furnace, but with approximately 50 bars in the furnace as a full load, the soaking time will be in the region of two hours.

The bars are then removed and cooled off in "still air". They should not be put in a position where drafts can play on them, otherwise they will harden somewhat.

One bar is then taken from the batch at random, and a standard test piece is made from it. This test piece should comply with the yield test laid down in Specification No. 18, which calls for a yield of not less than 58,500 psi.

If the yield is below this figure, then a hardening and tempering treatment must be given. Hardening is from the normalizing heat, but the bars are quenched in oil, the tank being suitably water jacketed or cooled by some other method. This leaves the bars in a hard state and they have to be tempered down to the condition required. They are soaked in the furnace for a period of about four hours at 1150 to 1200° F., a temperature which is determined by experiment, as certain makers' steels require different temperatures than others. After the bars have been soaked through they are cooled off in air.

The types of furnaces used in the forging and heat treatment of rifle and machine gun barrels are many, and for forging must be capable of temperatures up to 2400° F. They can be either coke, gas or oil fired, depending on local conditions. With normalizing, hardening and tempering furnaces, it is necessary to have proper pyrometric control, and the regulation of temperatures should be within close limits.

Recording of temperatures on continuous charts will be found of great advantage, as temperature variations can be readily seen and immediately investigated.

A machine gun barrel, by reason of the rate of fire (and under certain circumstances the number of rounds fired per minute) may reach a temperature far above that of a rifle barrel. The machine gun barrel therefore is normally made from a good class of alloy steel such as nickel-chromium, molybdenum, or chromium-molybdenum steel. Each has to be suitably heat treated.

The tensile strengths of the above types of steel are in the region of 100,000 to 125,000 psi. To attain this and put the steel in a satisfactory state for machining, a hardening and tempering treatment is necessary.

Bars or forgings are heated at 1560 to 1580° F. and quenched in oil. This produces a hard steel with a fine grain. The blanks are then heated to 1200° F. and cooled off in still air. If the alloy steel bars are machined in this condition, they spring badly as the material is removed, particularly in the turning and grinding operations. To eliminate this, the following stabilizing heat treatment is given to the bars:

They are first straightened by hand or in a suitable machine, and then held in a furnace, for a time depending on the bulk of metal, at a temperature of 90 to 100° F. below the tempering temperature. This does not affect the hardness of the bars, but it largely eliminates the stresses set up by previous heat treatments.

It is particularly necessary that the heat treatment furnaces have an even heat throughout their soaking zone, else different hardnesses along the length of the barrel bars are bound to arise, and great difficulty will be experienced in the boring and rifling operations. For this reason temperature control should be maintained within close limits.

T. Denness, *Capt.*
Assistant Director of Ordnance Factories
(Machine Guns)
British Ministry of Supply

NECESSITY FOR MAKING FULL SCALE TESTS

Moscow, U.S.S.R.

To the Readers of METAL PROGRESS:

In the past, the inventors of high strength metals for severe services and for places where the strength-weight ratio is important (like long span bridges, high speed machinery, and aircraft), have given most attention to the formulation and manufacture of alloys with high elastic limit, ultimate strength, and endurance limit. These figures are derived from the testing of small, smooth specimens, whose shape is specified and whose surfaces are carefully prepared. Influence of numerous methods of heat treatment, cold working and so forth, was also investigated almost exclusively on smooth test specimens of standard small size. The tacit assumption, of course, is that articles prepared from such materials selected by such tests will also show increased serviceability — an assumption that is by no means quantitatively borne out in service.

A prime example of this fact is a series of tests made by Lürenbaum some four years ago on single-throw crankshafts. Twelve designs, varying principally in the contour of the cheeks and the shape of the counterbores, were tested, full size, in reversed torsion. All were made of a 0.45% carbon steel, uniformly heat treated to an ultimate strength of 70,000 psi. and 20% elongation in 5 diameters. Fatigue failures occurred in the crank bearing at stresses ranging from ±6500 psi. to ±23,000 psi. This shows that even in a well-designed machine part it is difficult if not impossible to approach the endurance limit possessed by material when tested under meticulous laboratory conditions.

Further experiments with the crank designs giving the highest endurance were then performed. In this series, various steels were tested. One striking result may be quoted, showing the simultaneous influence of shape (quasi-notch) and size. A high tensile chromium-nickel-molybdenum steel, heat treated to a strength of 170,000 psi., had an endurance limit (small laboratory specimens) of ±52,500 psi., but the full sized crankshaft made therefrom withstood reversed torsion of only 11,500 psi.! Another conclusion became obvious: The respective differences between endurance limits of small laboratory specimens, of tubes the size of the crankshaft bearings, and of the entire crankshaft, were not constant, steel to steel. It is therefore impossible to predict the behavior of large parts of intricate form from tests on small scale bars or of unit shapes contained in the full sized parts.

The principal problem, therefore, before the testing engineer is to find those characteristics which influence these divergent results. In every case, model tests should verify the simpler laboratory tests before a new alloy of promising properties is approved for use. Much work lies ahead in the design and manufacture of such testing equipment. Its wide use will, however, establish much more clearly the correct fields of use of more economical materials, which at present can only be guessed at as long as we depend on laboratory tests of small smooth specimens.

JACOB B. FRIEDMANN
Physical Metallurgy Laboratory
Institute for Aircraft Materials

A FOSSIL GHOST!

Skeletons of Animals Around a Dried Up Water Hole. Discovered by Gerard H. Boss in a welded high speed toolsteel. (2000 ×)

Hard nitrided surfaces are favored on many aircraft engine parts, and this recently has led to a great expansion in the use of the nitriding process. Anhydrous ammonia is the usual source of the required gas. Anhydrous ammonia is also increasingly used for the production of protective atmospheres and special atmospheres for copper brazing and dry cyaniding or carbo-nitriding. Hence it is timely to present facts about the material and its safe handling.

HANDLING *of* LIQUID AMMONIA *for* NITRIDING *and* OTHER ATMOSPHERES

BY C. V. SNELL
Technical Advisor, Armour Ammonia Works, Chicago

ANHYDROUS AMMONIA is manufactured by direct reaction between purified nitrogen and hydrogen, and is therefore very pure (guaranteed by most manufacturers to be 99.95% NH_3 or purer) and free of water. Ammonia at atmospheric temperature and pressure is a gas, but by compression and refrigeration it condenses into a colorless liquid at $-28°$ F. It is put into 100 or 150-lb. tanks or cylinders at this temperature and the container tightly closed. As the cylinder and contents acquire heat from the outside atmosphere, the liquid ammonia tends to evaporate (boil), but since it is confined in a strong steel cylinder, only a little can evaporate until the pressure of the ammonia gas occupying the "unfilled" portion of the cylinder increases to a point where gas and liquid are in equilibrium at the given temperature (and pressure). Exact figures are given in Table I, from National Bureau of Standards' Circular No. 142.

Table I — Properties of Gaseous and Liquid Ammonia at Various Temperatures

Temperature, °F.	Gage Pressure of Liquid Ammonia, Lb. per Sq.In.	Gas Density at Atmospheric Pressure, Cu.Ft. per Lb.	Liquid Density, Lb. per Cu.Ft.
−28	0	18.0	42.6
0	16	19.3	41.3
10	24	19.8	40.9
20	34	20.2	40.4
30	45	20.5	40.0
40	59	21.1	39.5
50	75	21.6	39.0
60	93	22.0	38.5
70	114	22.5	38.0
80	138	22.9	37.5
90	166	23.4	37.0
100	197	23.8	36.4
110	232	24.2	35.8
120	272	24.6	35.3
140	364	25.5	34.0
160	478	26.4	32.7

From this table it can be easily figured that one 150-lb. cylinder of ammonia will yield approximately 3400 cu.ft. of ammonia gas, at ordinary temperatures and pressures. (See Table I for volume per lb. at various temperatures.) When passed through a dissociator, this will double in volume, yielding a mixed gas consisting of 75% hydrogen and 25% nitrogen, according to the equation:

$$2NH_3 \rightarrow 3H_2 + N_2$$

This mixed gas is a very convenient source of hydrogen for heat treatment and other industrial purposes. (Quite pure nitrogen may also, on occasion, be obtained by burning it in air and removing the resulting moisture, excess oxygen, and incidental CO_2.)

Dimensions of standard containers are given in Table II. The tube type cylinder looks

Table II — Standard Ammonia Cylinders

	Bottle Type		Tube Type		
Ammonia capacity	100 lb.	150 lb.	50 lb.	100 lb.	150 lb.
Average tare weight	130 lb.	187 lb.	107 lb.	187 lb.	237 lb.
Outside diameter	12½ in.	15 in.	10 in.	10 in.	12 in.
Overall length	56 in.	57½ in.	46 in.	7 ft.	7 ft.
Minimum volume	3.0 cu.ft.	4.5 cu.ft.	1.5 cu.ft.	3.0 cu.ft.	4.5 cu.ft.

like a section of husky pipe, with closed bottom and recessed top to protect the outlet valve. They are intended to be stored, moved, or used while in a horizontal position. For locations and uses where the container is more conveniently stood on end, the bottle types are available with protective cap screwed over the outlet valve; they can be handled like any compressed gas cylinder.

In accordance with Interstate Commerce Commission regulations, cylinders are filled to 54% of their water-weight capacity (approximately 86% of their maximum volume at average storage temperatures). Because of the high coefficient of expansion of liquid ammonia, the ammonia in a cylinder filled in accordance with I.C.C. regulations will expand to fill the cylinder completely at 145° F. Any further rise in temperature will result in a hydraulic pressure which may burst the cylinder. For this reason cylinders should be stored in the shade and should under no circumstances get over 120° F., to allow a reasonable safety factor.

Outlet connections on the valves are threaded for ½-in. standard black pipe, and the outlet is recessed slightly for a gasket, as shown in Fig. 1. Leakage at this point is simply prevented by running the threads back 2 in. on an extra heavy ½-in. pipe nipple and screwing a lock nut back on the threaded nipple. The washer is then placed on the nipple which is screwed into the valve connection and the lock nut pulled down with a wrench, thus making a tight closure with the composition gasket between the cylinder valve and the lock nut. Lock nuts and washers may be obtained from the ammonia supplier.

Since most metallurgical uses are for gaseous ammonia rather than liquid ammonia, it is necessary to arrange the cylinders so that gas rather than liquid is discharged from the cylinder. This will always occur if a bottle is standing upright. In the tube type, the cylinder must be placed so that the outlet points down, whereupon the interior dip pipe shown in Fig. 1 will point upward; its end is close to the sidewall of the cylinder and therefore above liquid level.

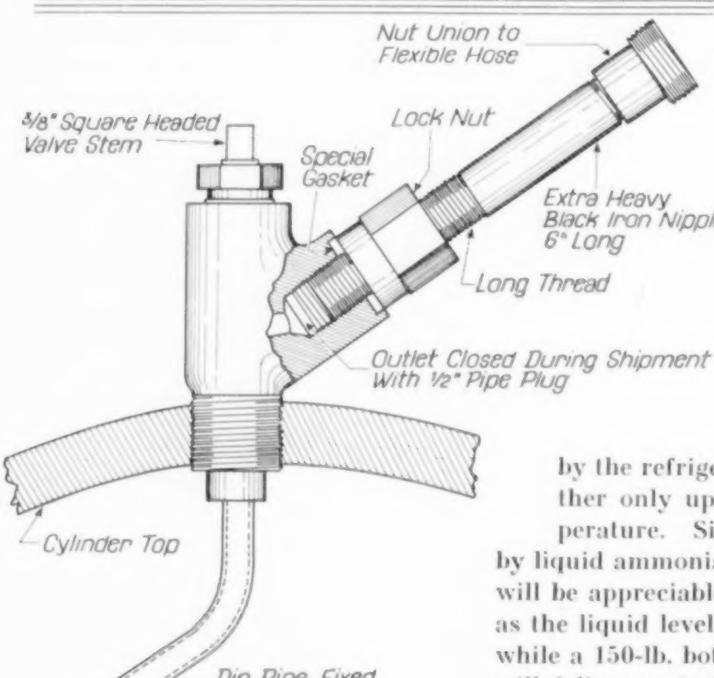
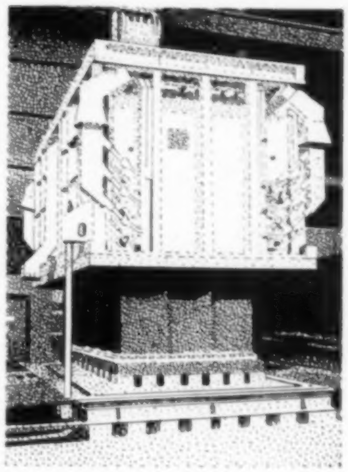


Fig. 1 — Sketch Showing Preferred Method of Making Leak-Proof Connection to Cylinder Valve

One of the first questions usually asked is the number of cubic feet of ammonia one cylinder will supply continuously without "freezing up" due to the refrigerating effect of the vaporizing ammonia. The rate of vaporization is dependent on the rate of heat absorption by the volatilizing liquid, since it is obvious that when the liquid ammonia remaining in the cylinder is chilled to −28° F. by the refrigerating effect of the vaporization, it will gasify further only upon absorption of heat to raise it above this temperature. Since that portion of the cylinder which is wetted by liquid ammonia is the only area through which the heat transfer will be appreciable, the rate of vaporization will obviously decrease as the liquid level in the cylinder falls. This explains the fact that while a 150-lb. bottle standing vertically at about room temperature will deliver up to 100 cu.ft. of gaseous ammonia per hr. when nearly full, it will deliver a maximum of only approximately 30 cu.ft. as it approaches dryness.

From our experience, either a bottle or tube type cylinder (150-lb. size) standing vertically may be expected to deliver to dryness up to 30 cu.ft. of ammonia gas per hr. Cylinders lying horizontally will discharge gas at a little higher rate, say 50 cu.ft. per hr.,

since as they approach dryness, the liquid ammonia within the cylinder will be spread over a comparatively larger area, thus giving more surface for heat transfer. Obviously, a rate of flow higher than that allowed by the prevailing conditions will cause the pressure within the cylinder to drop so that the desired rate of flow cannot be maintained. Also, if the cylinder is not weighed, it may be thought to be empty and thus several pounds of ammonia may be wasted. (The only way to be sure a cylinder is empty is to weigh it.)

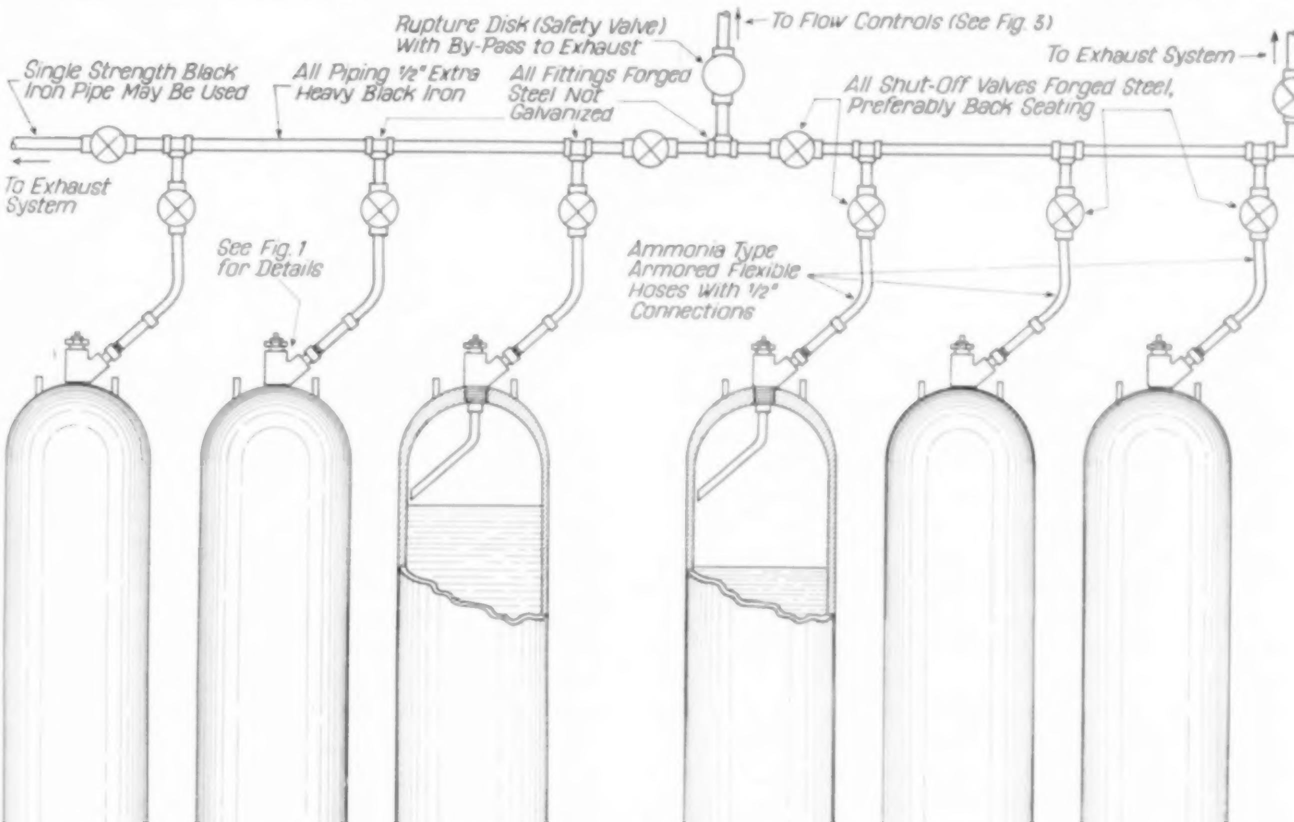


For continuous operation it is necessary to "manifold" cylinders, so that one cylinder (or a bank of cylinders) is in reserve while the other is discharging. Recommended piping arrangements are shown in Fig. 2. This permits all or any one cylinder in a bank to be cut off service and replaced without interrupting delivery of gas. Empties should not be left connected to the manifold with the valves open, for if their temperatures are lower than that of the full cylinders, some gas will enter and condense in the empties.

In the set-up shown in Fig. 2 the spare bank may be turned on simply by opening the main shut-off valve on the line to the spare bank and simultaneously closing the main valve to the empty bank. The small amount of residual ammonia may then be bled into the exhaust system by opening the valve to the bleed line, and discharged safely outdoors.

Because the heat will transfer rapidly only on the walls which are wetted with liquid, the exterior condensation which takes place on humid days indicates fairly closely the liquid level in the cylinder. If the ammonia is drawn from the cylinder too rapidly, frost will appear on the cylinder wall. This, of course, means that the temperature of the

Fig. 2 — Piping and Valves for Convenient and Safe Manifold. Caution: Use no galvanized pipe or brass fittings. If tube type cylinders are used they may be racked on stout wall brackets, horses, or trucks



liquid ammonia is less than 32° F. and that the temperature where vaporization will cease is being approached. Therefore, an additional cylinder should be hooked up to the manifold.

It is inadvisable to heat cylinders, in order to increase the rate of discharge, other than to have plenty of space heating equipment in the manifold room. It is too easy to get a bursting pressure on a full cylinder. Exterior vaporizers are readily constructed and are perfectly safe when fed with *liquid* gas from the cylinder.

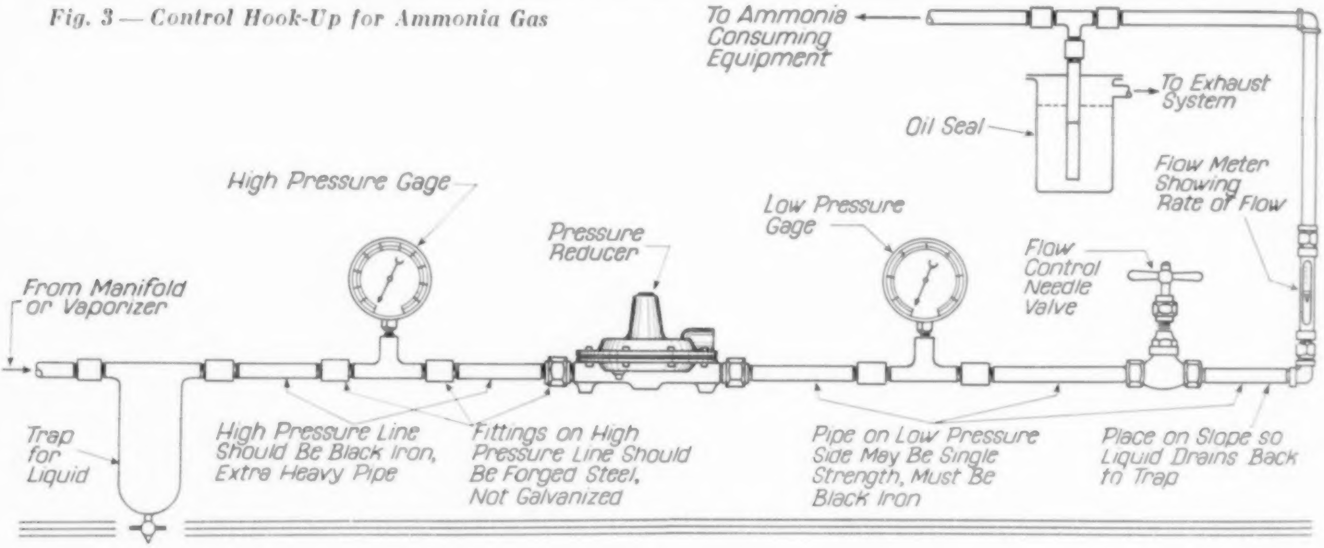
Auxiliary Equipment

The proper connector, at the cylinder, is shown in Fig. 1. The outer end of the long nipple shown should be fitted with a steel nut union of the tongue-and-groove type and an armored flexible hose, both designed for use with ammonia. The shut-off valves in the manifold line (Fig. 2) should be of a type designed for ammonia, preferably back-seating so the packing does not have to withstand the line pressure.

The line leading from the manifold, or from the vaporizer if one is used, may be equipped with a rupture disk as a safety measure and this should be followed by a pressure gage. Since the pressure of ammonia under ordinary storage temperature is around 125 psi., it is usually thought advisable for accurate control to install a pressure reducer, a low pressure gage, a flow control such as a needle valve, and a flow meter, as shown in Fig. 3. The variable orifice type of flow meter is preferred to the dial type with constant orifice, since the latter may become partially blocked with scale, thus giving erroneous flow rates. On some equipment an oil seal is included consisting of a tube extending down into several inches of oil, which is sufficient to hold normal pressures. If the line leading to the furnace should become obstructed, the oil will be blown from the seal, thus releasing the pressure. Pressure gages, reducing valves, controls, flow meters, and safety relief seals are usually supplied by the furnace manufacturer, but in all cases should be especially constructed for use with ammonia. When in doubt, go to your ammonia supplier for advice.

Pressure piping should be extra heavy black pipe (not galvanized), from ½ to 1½ in. diameter depending on the amount of gas to be passed. Welded joints are preferable, although steel nut unions are good; for larger sized pipe use 4-bolt flanges at necessary mechanical joints. Joint compound should be litharge in glycerine. Test for ammonia leaks with fumes from a bottle of concentrated hydrochloric acid, or a burning sulphur taper. Insulate the line pipe if it goes through any cold space.

Fig. 3 — Control Hook-Up for Ammonia Gas



Principal safety precautions have already been given. Foremost is care against overheating of cylinders beyond summer *air* temperature. Cylinders should never be inter-connected so liquid can pass from one cylinder to another, else a cylinder, thought to be empty, give trouble. Within the range of 16 to 27% NH_3 in air, explosive mixtures occur, and this should be watched when flushing out furnaces and containers.

Danger from a bad leak can be minimized by strong water spray, since ammonia is quite soluble. *Never* try to neutralize it with acid.

For emergencies an approved gas mask should be handy. Ammonia burns in the eye or mucous passages may be relieved, prior to reaching the hospital, by liberal douching with 2% boric acid solution — a necessity in the first aid cabinet. Adequate ventilation is the best safeguard.

SILVER SHORTAGES*

LACKING anything but scanty information concerning foreign markets, only the conditions existing in the Western Hemisphere can be discussed. As for the situation in the United States, the transition of silver from a civilian to a war commodity frequently involved a sharp conflict between the natural law of supply and demand, politics, and control administered by Government agencies. Statistics follow:

Western Hemisphere Silver Production
(In millions of fine ounces)

	1942	1941
United States	54	69.1
Canada	22.3	22
Mexico	74	78.4
South America	29	28.1
Central America and the West Indies	4.3	4.3
Total Western Hemisphere	183.6	201.9

U. S. Government Silver Acquisitions

	1942	1941
Domestic production	48	70.5
Foreign silver	14.4	72.6
Miscellaneous receipts	1	0.7
Total	63.4	143.8

1942 purchases by the U. S. Government were by far the smallest since the silver-buying program was inaugurated. We estimate the total Treasury holdings at the end of 1942 as being 3,342,600,000 oz., which includes the silver content of coins in circulation. Of this about two billion ounces are used for coin or pledged as backing for silver certificates, and about 1⅓ billion ounces are free of this restriction.

For the eight years prior to 1942 the arts and industries in the United States had been using only silver of foreign origin, a situation which resulted from the premium prices paid for newly mined domestic silver by the Treasury Department under authority of the law of July 6, 1939, which fixed the buying rate at 71.11¢ per oz. Foreign supplies were ample, and the yearly average price (1933 to 1941) ranged from 34.7 to 48.0¢ per oz., New York, except in 1935 when it averaged 64.3¢. In November 1941 a severe shortage was threatened because of the agreement between the governments of the United States and Mexico whereby the Treasury Department undertook to buy 6,000,000 oz. per month of Mexican newly mined silver direct from the Mexican Government at 35¢. Industry was able to obtain its silver requirements by raising its bid to 35⅜¢. (Mexico's production accounts for the major portion of the silver imported into this country.)

A silver shortage was anticipated by Secretary of the Treasury Morgenthau in February 1942, who personally advocated the repeal of all silver legislation as a help in controlling inflation, an announcement which precipitated immediate action by those Congressmen opposed to repeal, who ended any immediate prospects for the unrestricted release to industry of Treasury stocks and newly mined domestic silver.

Meanwhile, the Attorney General having ruled that it was legal, the Treasury Department agreed to lease to the Defense Plant Corp. all unpledged bullion, and to deliver it when needed for manufacture into busbars or other non-consumable forms to be used for war purposes.

The War Production Board, however, felt that silver supplies would still be insufficient for war needs. At a meeting of the Senate Special Silver Committee (May 28) it developed that the W.P.B. and Defense Plant Corp. wanted the silver on loan and not for consumption. While no basic change in the silver legislation was sought, influential senators refused to act fearing that the purchase program would be nullified. Senator McCarran of Nevada later blocked any action unless it involved an increase in the buying rate for United States silver to $1.00 per oz., maintaining that if the price were increased, production would be stimulated sufficiently to satisfy the demand. But because the demand from industry was entirely for the cheaper foreign silver and all domestic silver was being purchased by the Treasury for addition to its monetary stocks, the Senator's suggestion was not accepted as a solution.

The imminent "very critical situation" to which Senator McCarran alluded had already materialized so far as civilian industry was concerned. Imports into the United States were somewhat below normal due to delays and perhaps losses in shipment, and to some reduction in Latin America's production caused by a shortage of equipment and mine supplies. Meanwhile, continued large consumption of silver in customary products, its substitution for essential materials such as nickel and copper, and new-found uses in the war effort had enlarged the demand for foreign silver to a point where it exceeded imports. This condition resulted, during April, in the indefinite postponement of deliveries against non-priority orders and, commencing with the month of May, in the rationing of available foreign silver for all purposes other than war or essential products. Private industry, of its own initiative, instituted this rationing.

*From "27th Annual Review of the Silver Market", 1942; by Handy & Harman.

For the purpose of checking inflation, the Office of Price Administration on April 28 established maximum prices to apply to bullion, semi-fabricated products, and articles sold at retail. But the regulation on bullion did not apply in Mexico, and metal could be obtained there legally by paying a premium over the United States ceiling price, a premium which was small at first, but which increased substantially as competition became keener.

Naturally the silver sold in this manner decreased correspondingly the amount of Mexican production obtainable through customary distributors, and this shortage in turn caused stricter rationing for the non-essential user of silver, thereby creating an incentive on his part to seek "outside market" metal. The progressive curtailment of supplies from normal sources brought about by this vicious circle, coupled with an ever-growing demand for silver for war and other essential purposes, could have but one logical outcome. By July 1, civilian rationing was reduced to the zero point and the silver-using industry of the United States was deprived of any new allotments whatsoever of foreign silver except for priority orders.

Other regulatory actions followed:

July 21; W.P.B.; private importation of silver prohibited except by special authorization.

July 29; W.P.B.; use of foreign silver in civilian uses sharply limited.

August 10; O.P.A. established ceiling price of 35⅜¢ on foreign bullion. (Since premiums in the "outside market" were higher, this shut off such purchases altogether.)

August 22; State Department and O.P.A. increased price of imported bullion to 45¢.

Sept. 17; Treasury agreed to sell at 45¢, for war purposes, about 5,000,000 oz. of "silver ordinary", not acquired under monetary legislation.

Oct. 1; W.P.B.; consumption of foreign silver limited to orders rated A-3 or higher.

The 45¢ price brought out so much silver that only about one fifth of the Treasury's offering was bought by qualified manufacturers.

The inflow of newly mined foreign silver continued to exceed the demand covered by priority orders, and as a result arrangements were completed whereby the Metals Reserve Corp. acquired for stockpiling (at 45¢ per oz.) such excess amounts of newly mined foreign silver as manufacturers were unable to consume. This arrangement is greatly preferable to acquisition by the Treasury, whereupon the silver would become part of the monetary reserves and consequently restricted against resale. In accordance with this plan, purchases of newly mined foreign silver by the Metals Reserve Corp. were made throughout November and December. *(Cont. on page 274)*

PLATINUM IN COMMERCE

BY CHARLES ENGELHARD
President, Baker & Co., Inc.

INCREASED consumption of the platinum group metals (Pt, Pd, Ir, Rh, Ru, Os) has caused the W.P.B. to restrict the use of platinum for jewelry. The most important war-time use is as a catalyst for producing HNO_3 and H_2SO_4 for munition plants. Various electrical uses are second in importance and are followed closely by the glass and the electro-chemical uses. There are numerous new and interesting developments with platinum in the latter field. Other important uses of platinum — as well as of palladium, its companion metal — include catalysts for operations in organic chemistry, such as the production of essential components of vitamins.

Many of the industrial fields have also shown heavy demands for platinum-clad materials. Essentially, these consist of a layer of platinum bonded to silver, nickel, steel, or another less noble metal, providing at a lower cost the resistance to corrosion and oxidation of platinum with the required strength of the base metal. They have been used to replace other corrosion-resisting materials which were found either inadequate or are required for other purposes. Platinum-clad equipment frequently permits chemical reactions to be effected in plant operations which are impractical with less noble materials. Thus, delicate steps in food and drug processing may be endangered by metallic contamination, but are now using platinum-clad metals to protect the product. Vitamin producers, for instance, are using this type of equipment in the more severe stages of processing.

In the dental field, improved economic conditions have contributed to an increased interest in better dentistry, and palladium, as well as gold and platinum, have extended their scope of usefulness for full and partial dentures, inlays and clasps.

In restricting platinum for jewelry purposes, the W.P.B. pointed out that ample supplies exist of palladium, platinum's twin metal. Palladium is not new to the jewelry trade. It has been used for a number of years, being hardened with ruthenium, and is similar in appearance to platinum.

As far as the future is concerned, it is likely that many of the war-developed industrial uses of platinum will remain. Palladium will continue to supplement rather than supplant platinum, and probably also will continue to find, with platinum, increased industrial application.

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PERSONALS

Promoted by Standard Steel Works Division of the Baldwin Locomotive Works, Burnham, Pa.: **John D. Tyson**, formerly chief metallurgist, to manager of sales and metallurgy; **George S. Baldwin**, formerly superintendent of the openhearth, to chief metallurgist.

E. R. Mertz, formerly chief metallurgist with the U. S. Spring and Bumper Co. of Los Angeles, is now chief metallurgist of Bendix Aviation, Inc., of North Hollywood, Calif.

In the Army: **Edwin K. Smith**, formerly metallurgist at the War Department, Washington, now a major, Ordnance Department, Engineering Offices, Tank-Automotive Center, stationed at Detroit.

I. W. Erickson, formerly with J. I. Case Tractor Plant at Racine, Wis., is now an ensign U.S.N.R., doing metallurgical work, assigned to a naval ordnance plant.

Anning H. Smith, formerly with Phelps Dodge Corp., Philadelphia, is now connected with the Copper Division of the War Production Board in Washington, D. C.

Walter Swardenski, formerly machine tool buyer for Caterpillar Tractor Co., Peoria, Ill., is now purchasing agent for the Caterpillar Military Engine Co., Decatur, Ill.

Robert K. Kulp, formerly research metallurgist, Steel and Tube Division, Timken Roller Bearing Co., is now in charge of the research and development department for Jessop Steel Co., Washington, Pa.

Cecil J. Bier, formerly with Moraine Products Division of General Motors Corp., Dayton, Ohio, is now employed as metallurgist for the H. L. Crowley Co. of West Orange, N. J.

John T. Bryce, formerly with Spicer Mfg. Co., has spent six months studying magnesium metallurgy and fabricating methods in England and is now working on metal refining and fabricating with Basic Magnesium, Inc.

Norman E. Woldman, chief metallurgical engineer, Eclipse-Pioneer Division, Bendix Aviation Corp., and chairman of the War Products Advisory Committee, New Jersey Chapter, has accepted a lectureship in the evening graduate school of Stevens Institute of Technology, teaching a course in non-ferrous metals.

Robert W. Lindsay, formerly with the Association of Manufacturers of Chilled Car Wheels in Chicago, has joined the staff of the Sealed Power Corp., Muskegon, Mich., as research metallurgist.

THE ZINC INDUSTRY IN 1942

By ERNEST V. GENT, Secretary, American Zinc Institute, Inc.

IN 1942, production continued to be the keynote of the zinc industry. In line with earlier plans, refining and smelting facilities were expanded still further but, because of priority and manpower problems, the scheduled peak will not be reached until the second quarter of 1943. Although total output for the year was well ahead of 1941, the *rate* of production in December, which was expected to break all records, more clearly reflects the progress made toward the objectives of the smelter program.

High Grade Metal

Another important increase during 1942 in high grade metal output included not only additions to existing plants, but the starting of a new one. To supplement high grade tonnage, redistillation capacity was greatly increased and will again be largely increased by the time peak production is reached in 1943. This gives extraordinary flexibility in dealing with the demand for grades, but does not add to the over-all supply of metal, since redistillation merely converts lower grades of feed metal into high grade zinc.

It is becoming more generally recognized that the zinc smelting capacity already scheduled is sufficient, or at least it will have to do. There is likely to be more future emphasis upon mine production, for this may prove to be the limiting factor.

Mine Production

Domestic mine production in 1942 will not be so very far off past performance. Sufficient imports, which are growing in significance, will have been found available to make up the difference required to operate smelters and refineries at maximum capacity. Estimates for 1943 are all predicated upon the belief that the economic needs will be recognized by Washington and that the necessary bases will be provided to maintain, if not increase, present activities at domestic mines. This is essential if metal is to be obtained and there is to be time to wrestle with manpower and other production problems.

In an effort to increase domestic mine production, a premium plan was announced early in the

(Continued on page 258)

ZINC IN 1942

(Continued from page 256)

year for over-quota production of zinc after February 1, 1942. The premium price was fixed on the basis of 11¢ at East St. Louis for slab zinc, as against the regular price of 8.25¢, the equivalent of an extra \$28.05 a ton for 60% concentrates to be paid to the miner by Metals Reserve Co. Late in the year this figure was raised to \$29.70.

Obviously, the success of such a plan depends largely upon the quota limits set, and as each operation is appraised on its own merits, a great deal of time was needed to determine initial quotas. Because of changing conditions related to both costs and grades, it has been found necessary to review and revise quotas from time to time in an effort to maintain output. While some disappointment has been expressed in the failure of the premium price plan to increase previous mine production, it must not be overlooked that, under the circumstances, the maintenance of past production is a considerable achievement.

In the view of some competent authorities, the current situation now calls for the liberalization and expansion of the premium price limits. If ore is to be mined at home in keeping with the needs of the enlarged smelting capacity, it appears obvious that the steadily falling grade of ore available must be utilized regardless of the increasing cost of mining and milling such ore. This applies particularly to the situation in the Tri-State district.

Beyond 1943, outlook for mine production is not particularly cheerful; but much will depend upon the approach to the immediate difficulties. If these problems are not solved, 1943 domestic ore estimates will need to be discounted, and the outlook beyond will seriously deteriorate.

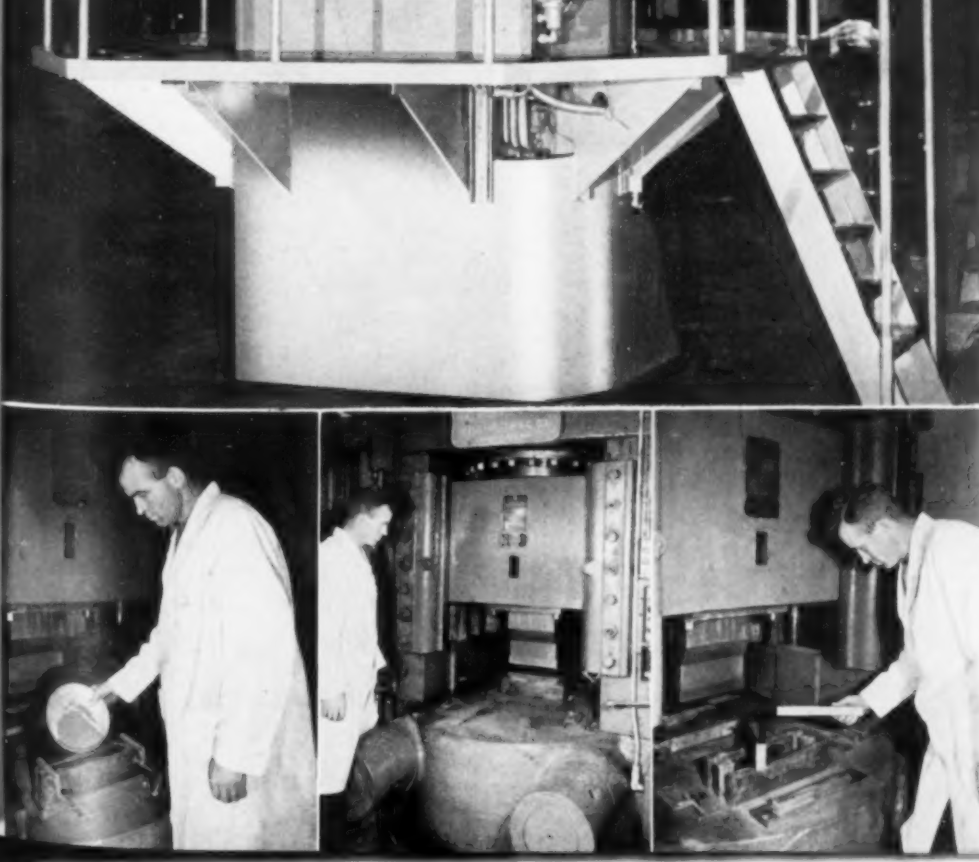
As to the price of the metal, there was no change in 1942 insofar as the producer and the consumer were concerned. The ceiling of 8.25¢ fixed on October 10, 1941 was maintained.

Government Controls

1942 saw increasing governmental control of zinc and its products. General Preference Order M-11, effective July 1, 1941, with its amendments, continued through May 31, 1942, and placed deliveries of slab zinc under the control of the Office of Production Management. While the Director of Priorities exercised this right with respect to a part of the output, the balance of the tonnage continued to be distributed by the industry until June 1, 1942, when an

(Continued on page 260)

POWDER METALLURGY
..Another Field for H-P-M Fastraverse Metal Working Presses



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ZINC IN 1942

(Continued from page 258)

amendment to Order M-11 prohibited deliveries except upon presentation of an allocation certificate issued by the Director of Industry Operations. Thus all the slab zinc has since been channeled through the hands of the War Production Board.

Restriction Orders

Conservation Order M-11-b, July 24, 1942, was the first direct restriction of the use of zinc. Except for U. S. Government and lend-lease account and certain other special exceptions, the use of zinc in stipulated items (List A) was cut in half to September first and thereafter entirely prohibited. The use of prime Western zinc in items not included in the list was reduced by 25% (50% in the case of other grades).

An amendment prohibited the use of zinc after October 10 to make closures for glass containers, one of the important uses of rolled zinc in normal times. Restrictions on the production of dry cell batteries were imposed on October 2, 1942, while another order restricted the use of zinc for printing plates.

Consumption

Naturally, as the war program progresses, uses change. According to published reports, galvanizing operations late in the year were found to be only about 40% of what they were a year earlier. It is reasonable to assume that, with the severe restrictions on both steel and zinc, galvanizing now is largely for war uses and the tonnage of zinc so used for civilians may be near the irreducible minimum.

As everyone knows, brass mill capacity has continued to expand, which calls for increasing quantities of zinc. Brass now takes first, instead of second, place in the outlets for zinc.

Exports continue to be significant. According to a recent statement attributed to the President, lend-lease and direct purchases of zinc by our Allies absorbed over 16% of our supply in the first half of 1942.

To date no shutdowns or delayed production of war materiel have occurred due to a shortage of zinc. As to the future, with reservations only with respect to the unforeseeable, given the necessary domestic mine production and ore imports, present scheduled smelting and refining capacity should be sufficient to provide all our own war needs, as well as those of our Allies. As is the case with practically all metals, civilian uses, unless essential, are not likely to get much consideration so long as direct military demands maintain.

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LEAD

(Continued from page 223)

content which runs between 0.040 and 0.080%, considerably higher than in the other grades. Chemical lead is always higher in silver, and copper-lead may run higher in silver than other grades. Although these grades are somewhat stronger than others, there are installations where still greater strength and rigidity are needed. In such cases an alloy may be used. The alloys also may have better corrosion resistance under some operating conditions.

One of the most common lead alloys thus employed is antimonial lead containing up to 12% antimony, but since this alloy loses strength rapidly at elevated temperatures, its principal use is with temperatures up to 210 to 250° F. For high temperatures an alloy of lead with 0.05 to 0.06% tellurium has been employed quite extensively in the last few years because of high resistance to fatigue failure. This alloy work hardens and is said to have good corrosion resistance, particularly against hot sulphuric acid. An alloy of lead with about 7% tin has also been used successfully in chromium plating operations, and a 1% silver alloy is used for insoluble anodes in electrolytic zinc refining.

Joints in lead used for corrosion resistant equipment are made by fusion welding, a method of joining that is commonly known by the somewhat misleading term of "lead burning". This method is used so that no metal other than lead will be exposed to corrosive attack. Likewise, it is necessary to see that the lead exposed to attack is homogeneous in composition in order that all exposed metal may resist attack uniformly. Therefore, if metal has to be added through the use of a filler, or so-called "burning bar", in making joints, the bar should have the *same* composition as the lead being joined. Thus, chemical lead should be joined by the use of a chemical lead filler bar, 6% antimonial lead by the use of a 6% antimonial lead filler bar, and so on. Oxygen and hydrogen are the most generally preferred gases for lead welding, but others, such as oxygen and acetylene, and oxygen and city gas, are also used.*

Forms of Equipment—Because of its low strength, lead is usually supported by some other stronger material, such as steel, wood or concrete. (Occasionally chemical equipment is made of cast lead alloy, but then

(Continued on page 264)

*See ⊕ Metals Handbook, 1939 Edition, page 245.

LEAD

(Starts on page 223)

the walls are unusually thick to gain the necessary strength; valves, pumps and fittings are also frequently made of cast lead alloy.) Sometimes the supporting structure may be merely a framework of steel, but more often the entire outer shell is made of strong material with a lead lining applied to it in various ways. Small tanks may simply have the sheet lead lining hung in them by turning the lead over the upper edge.

For better support the lining is often supported by 2-in. half-round steel straps fastened at frequent intervals inside the lead and through it to the outer steel shell. These straps are covered with strips of lead welded to the lead lining on either side. Vertical strips are usually about 24 to 30 in. apart, and tanks with high walls, say 10 ft. or more, also have horizontal supports.

Another method of support sometimes employed is lead rivets. These may be welded to the back of the lead lining, extend through holes in the shell and be riveted on the outside, or may be lead rivets extending through holes in both lining and shell. In the latter case the rivet head on the inside is welded all around to the lead lining.

The strap method of support is invariably used for lining the tops of closed equipment. Both for support and protection against abrasion, brick linings are often used inside lead linings, particularly where high temperatures are involved.

When heat transfer is important, lead linings may be bonded to the supporting shell and this is always done when equipment operates under a vacuum or where greatest strength is necessary. If temperatures are not high, tin or solder may be used to bond the lead to the steel, but there are also processes employing a non-metallic flux, which form a bond that can hold its strength up to about the melting point of lead.

Pipe — Horizontal runs of lead or lead alloy pipe are generally continuously supported in steel or wooden troughs, or in specially constructed sheet metal shells. Vertical runs are supported at frequent intervals, say every 18 in. Long runs are provided with expansion bends if they operate at high temperatures. When greatest strength is essential, lead-lined steel pipe may be used. The inside of the steel pipe is coated with a bonding agent such as solder and extruded lead pipe inserted. The lead is expanded under steam pressure against the warmed steel and is thus "sweated" to the steel pipe. *(Cont. on p. 266)*

LEAD

(Starts on page 223)

Lead or lead alloy pipe may be joined by welding or by welded flanges and bolts. Lead flanges are usually backed by loose steel flanges. Flanged joints are generally used for lead-lined steel pipe.

Heating or cooling coils, made of lead pipe, are important items in many pieces of chemical apparatus. Usually they are helical in shape but may take other forms. Lead spacers are welded at intervals, generally not more than 18 in. apart, around the coil between the turns for support. Where greater strength is needed, the coils may be made of copper tube completely covered with lead.

Commercial Products — The list below shows stock or standard manufactured items for use in industry or generally available at short notice in various parts of the United States:

- Angles
- Anodes
- Bars
- Bends
- Electrodes
- Evaporators (cast lead)
- Exhaust fans (cast regulus metal)
- Filters
- Gaskets (cast, stamped or asbestos filled)
- Grids, filter
- Laboratory equipment, dishes, bottles, fume ducts, etc.
- Perforated sheets
- Pipe and fittings (lead, lead-lined steel, steel reinforced)
- Pumps, rotary and centrifugal
- Rings
- Sheets
- Spacer blocks
- Spray nozzles
- Traps
- Valves, compression, gate, diaphragm, check
- Washers
- Wedges
- Wire

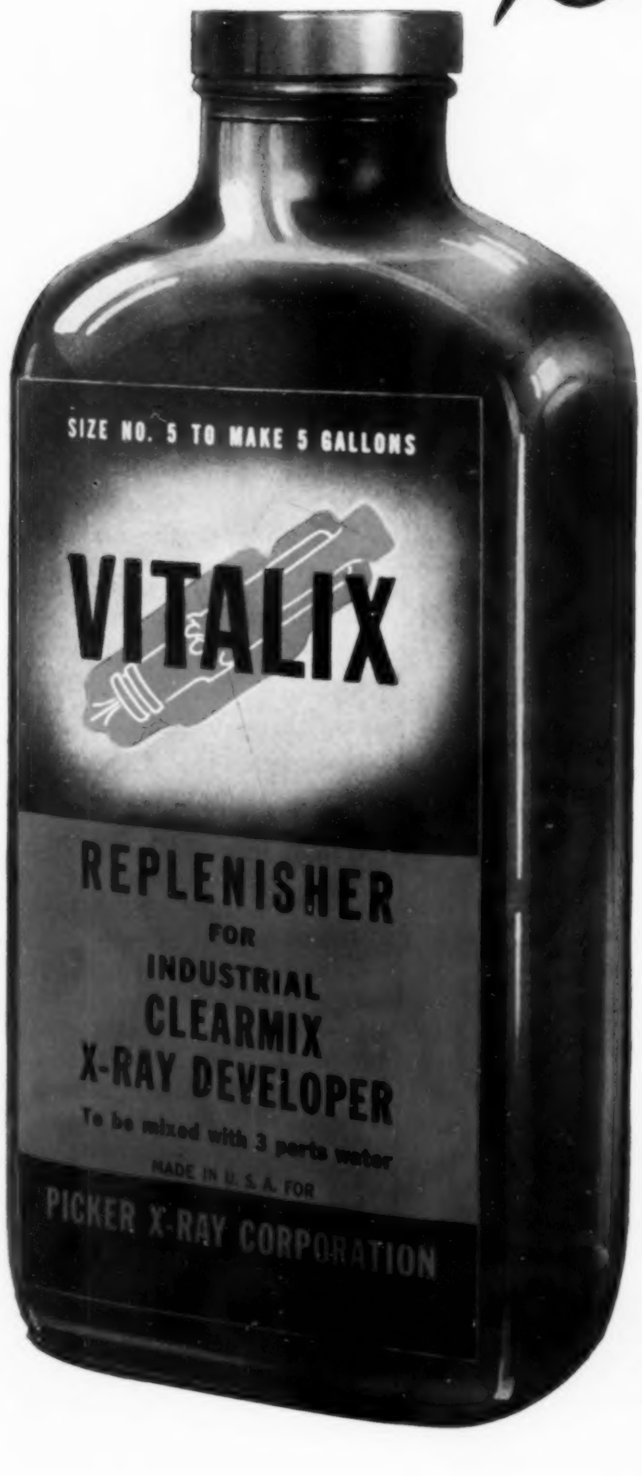
Thickness of sheet lead linings depends largely on the degree of corrosive attack. Rarely is sheet lead lighter than 8 lb. (1/8 in. thick) used in chemical equipment. Frequently different thicknesses are used for different parts of equipment, tank bottoms often being lined with heavier lead than sides because of greater wear. Abrasion may also be a factor in determining the correct thickness.

Sheet lead is designated by its weight per square foot, 1 sq.ft. of sheet lead weighing 1 lb. for each $\frac{1}{64}$ in. of thickness. This relationship holds true up to 16-lb. sheet lead, which is 1/4 in. thick. Sheet lead 1/2 in. thick is designated as 30-lb. sheet and 1 in. thick as 60-lb.

Thickness of lead pipe depends on several factors including corrosive attack, abrasion and the pressure to be

(Continued on page 268)

Best by test



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LEAD

(Starts on page 223)

handled. For instance if wall thickness is calculated in the usual manner to accommodate a given pressure, additional wall thickness is allowed to compensate for loss through corrosion or abrasion. Pipe 1½ in. diameter with ½-in. walls is commonly used with steam pressures up to 45 psi. The formula commonly used to calculate wall thickness is

$$P = \frac{2ST}{D}$$

where P is constant working pressure in psi., S is allowable fiber stress taken as 200 psi. for chemical lead at room temperature and falling to 80 psi. at 300° F., T is wall thickness in inches and D is inside diameter in inches.

To the wall thickness thus calculated must be added allowances for corrosion and abrasion. If the pipe is not used under pressure, then corrosion or abrasion is the principal factor, and the lightest weight of pipe generally selected under such conditions is the class known as "B" or "M" weight in sizes up to 2 in., and ¼-in. wall in larger sizes. Standard weights of lead pipe are designated by the actual inside diameter and by a letter showing the wall thickness or the weight per running foot.

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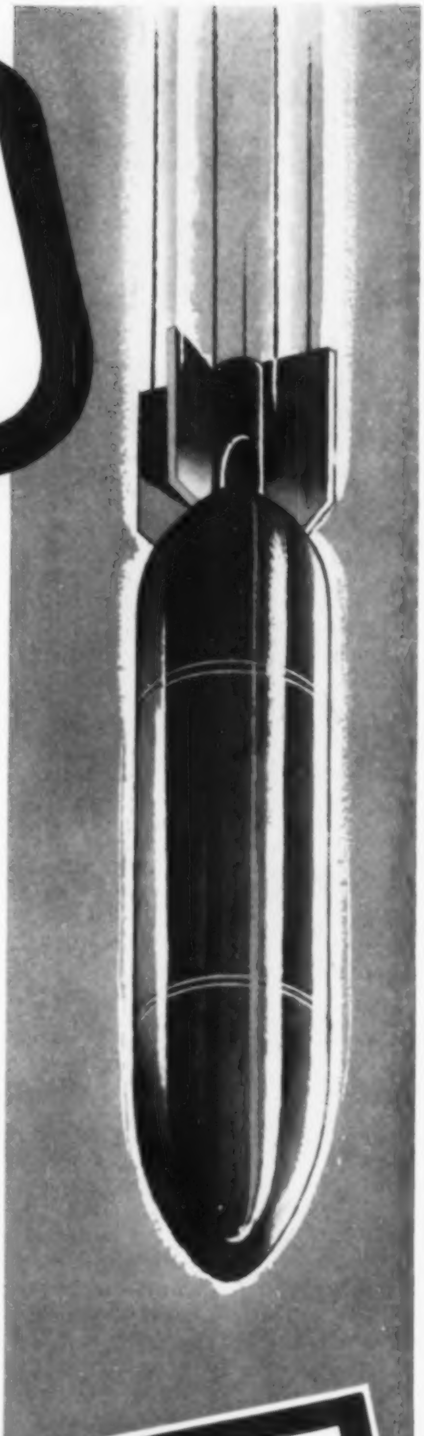

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PEENED SURFACES

(From page 215) in the usual manner, after which it was split longitudinally with a saw. The two parts curved, convex on the outer faces, indicating compressive stresses in these carburized faces. Analysis of the internal stresses in another carburized member by the method already described indicated the internal stress pattern shown in Fig. 11. Of interest here is the magnitude of the compressive stress in the carburized layer and the reduced stress (possibly even tension) in an extremely thin surface layer.

When carburized parts such as bearing races, wrist pins and gear teeth are ground we may expect the surface to be stressed in tension, as is indicated by the dotted line in Fig. 11.

The residual compressive stress in the carburized layer may be a hazard for members stressed in tension, because the tension stress in the core is equal to the working stress plus the tension stress due to the compressive pre-load of the case. For members stressed in bending and in torsion the internal compressive stress in the carburized case improves the fatigue strength of the part, except for the thin surface layer which, especially after grinding, is severely stressed in tension. It is, however, a simple matter to convert this thin tension stressed layer into stress in compression by a suitable peening or rolling operation.

With internal stresses of the magnitude shown in Fig. 11 we can readily understand why carburized parts are prone to warp during heat treatment, especially if the design is not symmetrical with respect to the internal stresses.

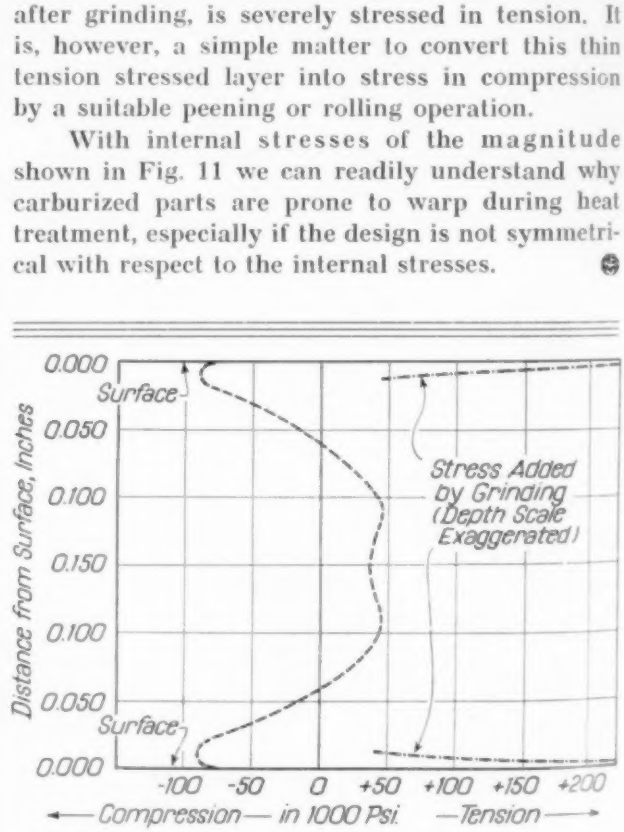


Fig. 11 — Dashed Line Showing Residual Stress in Steel Part Due to Carburizing and Hardening. Tension stresses added at very surface due to grinding are indicated by dotted lines

Sketched from life in one of the "BATTLE STATIONS" of the LEE WILSON ENGINEERING Co., Inc.

FRENCH, PRESIDENT

(Continued from page 217) In a recent reorganization by Hiland G. Batcheller, the new director of WPB's Steel Division, French finds himself as chief of the Metallurgical and Technical Branch in the Raw Materials and Facilities Subdivision.

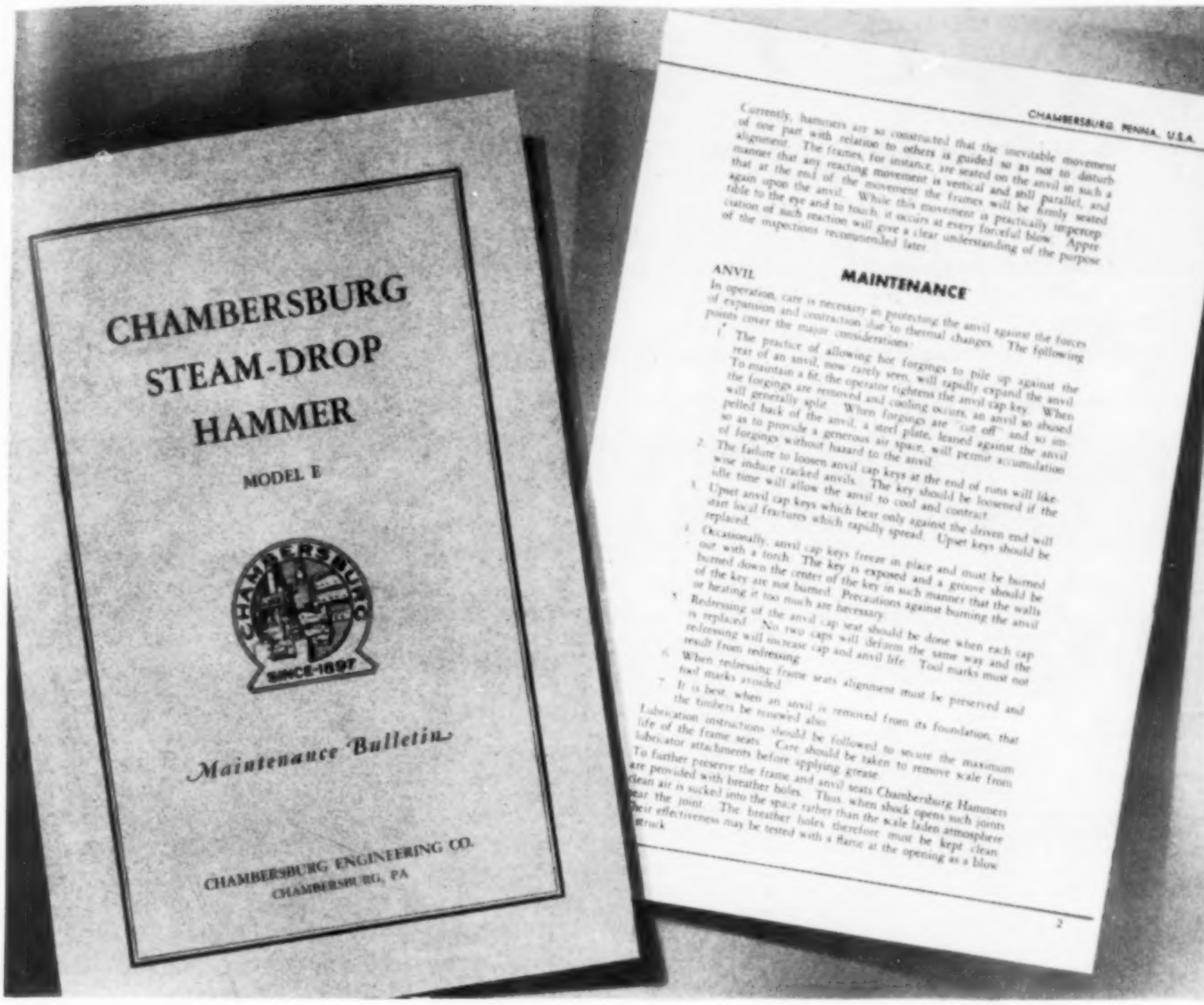
Herbert French's ability to sail on an even keel, no matter what the storm, has already been mentioned as his prime characteristic. One friend recalls that when he, a very young man, journeyed to the Bureau of Mines to get some information on a knotty problem, he approached the sanctum with much trepidation, only to be put at his ease at once by a gracious, pleasant and helpful gentleman. Indeed a chief characteristic noted by French's associates is that he was always genuinely interested in the welfare of "his boys". His personality was such that his subordinates both admired and liked him. Although he never hesitated to dress them down for an error, he was sincere in his praise of work well done. Differences of opinion with his men, usually on test methods or interpretation of technical data, sometimes led to vigorous arguments, but as soon as the storm was over the sun would shine again. His men liked the free and easy way in which they could argue and fight with him, secure in the knowledge that he would keep his temper and "take it" as well as "dish it out". He always backed up his subordinates, with the result that they would and did work their heads off for him. There wasn't any of the stagnation that besets the average Government worker in French's section at the Bureau of Standards.

As to his foibles and hobbies, chief is fishing. The big bass, mounted on a plaque in French's office, testifies that he successfully engages in other than purely metallurgical pursuits, though he gets a much bigger kick when his son catches the big one than when he does himself. A minor foible is gorging on chocolate cake — rather a notable gastronomic achievement!

Finally may be quoted two paragraphs of an appreciative letter by a fellow metallurgist:

"I have served with him, under him, and I too have been chairman of committees on which he served. He's a good committee-man always. So often, I have seen him sit back, and wait and listen, and then a tall, spare form would arise, and we would see the results of orderly, quiet appraisal of the important features, and always a recommendation.

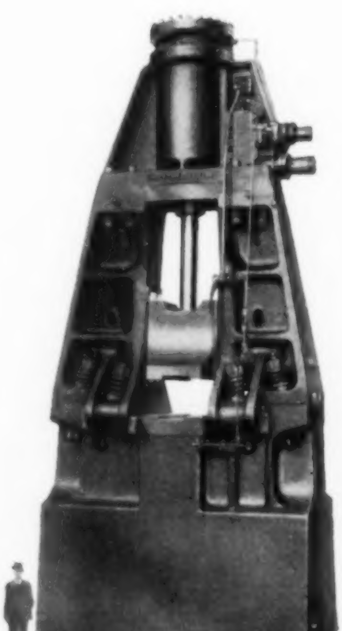
"Progressive, fair, honest, firm, a likable, pleasant adversary at times, a clear thinker, a sharer of knowledge, a seeker for truth — these go with H. J. French."



GET THE <u>MOST</u> OUT OF YOUR HAMMERS

DROP FORGINGS are more essential today than ever before. Millions of forgings per year are needed for the aircraft program alone. Production of hammers at Chambersburg is at an all time high... Yet more are needed. Older hammers must therefore do more than ever... must last longer. There are many ways to get more out of your hammers... perhaps you can get some new ideas out of our Model "E" Steam Drop Hammer Maintenance Book... Write for a copy... even if your hammers are *not* Chambersburgs.

CHAMBERSBURG ENGINEERING CO., CHAMBERSBURG, PA.



Chambersburg 35,000 lb. Model "E" Steam Drop Hammer

CHAMBERSBURG

HAMMERS · CECOSTAMPS · PRESSES

(Starts on page 250)

Non-War Industry — Before discussing the situation which confronted non-essential users of silver, it would seem proper to explain briefly how they came to remain in that category, for large manufacturers of sterling and plated silverware had generally been able to adapt their operations to war work.

Those remaining as non-essential users were small businesses where light machinery and hand labor performed a large part of the work. Such businesses were difficult to convert to the manufacture of needed products. Sometimes their very smallness interfered; more often their type of equipment was unsuitable or their hand labor unusable; and frequently the profits were insufficient to keep a business from losing money without being supplemented by profits from carrying on at least some of its customary non-essential work.

To these difficulties were occasionally added the human obstacles of unwillingness to convert or failure to recognize the necessity of making the attempt.

As previously described, the non-essential users of silver had been suffering from inability to obtain sufficient foreign metal since the early part of the year, and self-preservation caused them to attempt to obtain supplies from the only other available sources — namely, domestic production and Treasury stocks. The established price of 71.11¢ per oz. was something of a deterrent, but a greater one was the habit which silver producers have of delivering domestic silver to the U.S. Mints as soon as refined. In fact, producers were not permitted to sell domestic silver in any form until an order was issued on Sept. 3 by the Office of Price Administration.

Following this authorization, sizable purchases were made of domestic silver — in fact, the pent-up demand was so great as to necessitate immediate rationing of the available supply — a situation that quickly corrected itself because manufacturers of silverware discovered that the O.P.A. was unwilling to grant an increase in the price ceiling for finished articles, so the higher raw material cost had to be absorbed by the manufacturers.

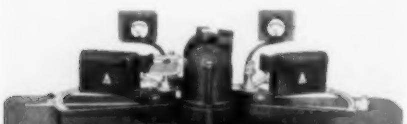
Early in September, the Silver Users' Emergency Committee was formed by the photo-engravers, fountain pen and pencil makers, and silverware and jewelry manufacturers, and instituted an aggressive campaign to acquaint Congress and the public with the situation. The basic argument was as follows: Domestic silver, costing 71.11¢ instead of 45¢ per oz., was not a satisfac-

(Continued on page 288)

NEW EQUIPMENT

X-Ray Crystal Analysis Apparatus

New X-ray crystal analysis apparatus, introduced by Philips Metalix Corp., 419 Fourth Ave., New York City, is said to be a practical production tool for fast, precise, angular measurements of



quartz, for oscillators, with a wide choice of analysis methods depending upon the character of the quartz piece to be measured. Tests can be made in a fraction of the time previously required, it is reported, and with relatively unskilled personnel.

Stud Welding Process

Stud welding equipment designed especially for construction of ship decks is said to meet the requirements of many other uses calling for the end-welding of steel sections to metal surfaces, according to Hollup Corp., Division of National Cylinder Gas Co., Chicago, and at substantial savings of both time and material. The gun is simple to use and eliminates personal judgment because all operations are fully automatic. With very

little practice the ordinary workman can consistently produce 150 perfect welded studs per hour. The method combines arc welding with impact or forge welding. Duration of the arc is automatically controlled by an electric timer in the control cabinet. At the exact instant the molten crater has been formed the gun plunges the stud into place in the molten metal and holds it in precise position.

Operator simply cocks the gun, places it in position and presses the pistol grip trigger. The entire cycle is then completed automatically giving joints so strong that the stud will break through the body before it will break at the weld.

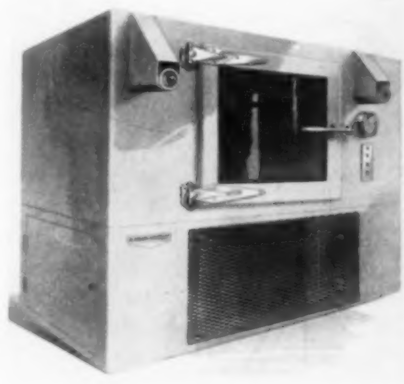
Manganese Alloy

New manganese base alloy with several unique physical properties is now being introduced as Chace Manganese Alloy No. 772, by W. M. Chace Co., Detroit, offering the possibility of improved design and performance of instruments and industrial controls. Its composition is unique in that over 70% of the alloy is manganese. In other commercial manganese alloys the manganese is present only as minor alloy addition. This high manganese content and the resulting distinctive physical properties result from the use of electrolytic manganese of a purity higher than 99.9%.

Useful characteristics claimed include *(a)* a high electrical resistivity, *(b)* a high thermal expansion rate, *(c)* a high vibration damping constant, and *(d)* a low thermal conductivity combined with *(e)* good ductility and *(f)* high tensile strength. Alloy is readily fabricated by the usual rolling, drawing and machining operations, and is available in form of sheet, strip and rod.

Cabinet for Sub-Zero Tests

Kold-Hold Mfg. Co. of Lansing, Mich., offers new "Hi-Low" machine in three temperature ranges for testing of aircraft instruments, batteries, wire, met-



als and various devices. Machine provides conditions required for testing under certain stringent aircraft inspection specifications. Temperature ranges are from —60° F. to +170° F.; from —80° F. to +170° F.; and from —90° F. to +170° F.

(See also page 286)

Today's Destination: BATTLE FRONTS
Tomorrow's: INDUSTRIAL U. S. A.
TENUAL ALUMINUM CASTINGS are proving their worth on far-flung battle fronts in planes . . . tanks . . . ships. And our castings will "come through" under all conditions because of our ability to meet the most rigid specifications of the armed service with speed and quantity production. This will be your guarantee of receiving quality sand and permanent mold aluminum castings when our shipping tags can again read: Destination U. S. A.
Illustration shows careful water pressure testing of an important aircraft aluminum casting
TENUAL
FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS
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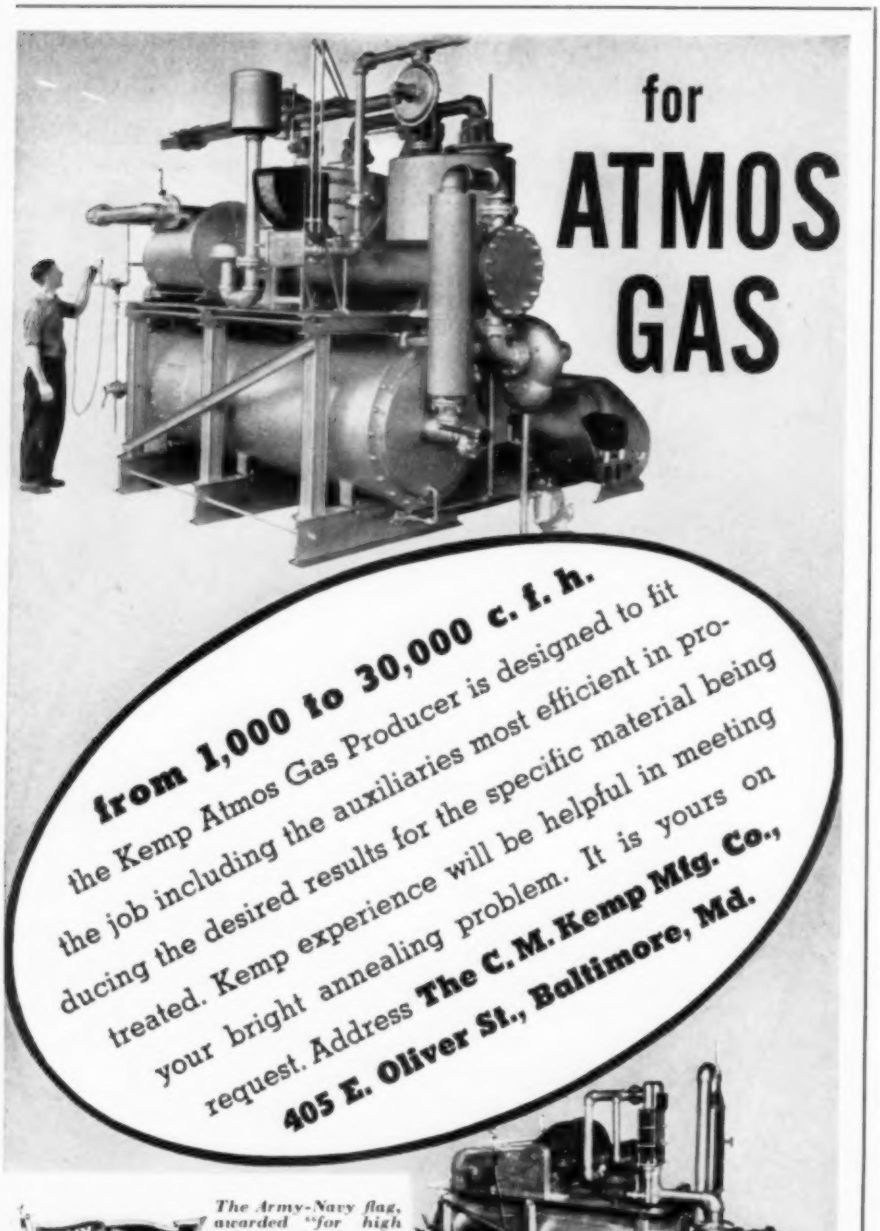
CLEVELAND, OHIO
W YORK, 111 Broadway • CHICAGO, 188 W. Randolph • DETROIT, Stephenson Bldg. • LOS ANGELES, 405 S. Hill
AKERS OF QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS

MORE NEW EQUIPMENT

Electronic Spot Welding Control

New electronic half cycle, synchronous control for precise operation of resistance-welding machines has been announced by the General Electric Co., Schenectady, N. Y. This control is based on a new tube, a new circuit which makes higher-speed welding possible, and a simplified initiating circuit — all of which improve performance and reduce maintenance. The new design also controls heat by the phase-shift method, adjusted by a dial mounted on front of the cabinet.



Fuse-Bond Process

Metallizing Engineering Co., Inc., Long Island City, N. Y., announces new "Fuse-Bond" process and equipment, whereby machine components may be prepared for metallizing electrically. Main advantage is said to be that it affords an adequate bond on the hardest surfaces, heretofore impossible or impractical to prepare by blasting or rough threading. It also simplifies the preparation of narrow edges, flat areas, and cylindrical parts having keyways or other interruptions in their surfaces. Operating on any 110 or 220-volt, single phase power line, this equipment fuses a rough deposit of electrode metal into the surface to be metallized. A special holder uses up to six electrodes at a time, depending on the size and nature of the surface to be prepared.

Anodizing Rack Life Prolonged

Recent engineering development in the field of insulation is said to have multiplied anodizing rack life, reduced rejects to a minimum and reduced current consumption to just what the work requires, according to Nelson J. Quinn Co., Toledo, O. The new insulant Bunatol has greater flexibility in keeping with the rack, and therefore does not become brittle, crack or peel when flexed. Because this flexibility is retained for the life of the insulation, it retains its efficiency and provides maximum protection for the rack until the contacts are entirely eaten away.

New Line of Metal Washing Machines

American Foundry Equipment Co., Mishawaka, has added a division for designing and manufacturing metal washing machines for industrial purposes. The new division will design and build machines for removing chips, dirt, grease and oil from machine parts, stampings and other manufactured products.

SILVER SHORTAGES

(Starts on page 250)

tory substitute for foreign silver, partly because there would not be enough, and partly because the Office of Price Administration had not raised the ceiling price for finished articles made of domestic silver. Therefore, to avoid any silver shortage in the war effort and to prevent the extinction of many silver-using businesses, Treasury silver should be made available for both essential and non-essential purposes. While no non-essential business should complain of being deprived of materials which were actually scarce, such a scarcity did not exist in the case of silver because of the hoard of unused metal held by the Treasury Department.

Senator Green of Rhode Island introduced a bill on behalf of the industry, making it legal for the Treasury not only to *lend* for non-consumptive purposes the silver pledged as backing for outstanding silver certificates, but also to *sell* for consumptive purposes the free or unpledged silver.

The Green bill brought forth immediate opposition from the silver bloc. The feeling persisted among "silver senators" generally that the release to industry of silver acquired for monetary purposes should not be permitted, except as a definite war measure, because such action tended to weaken the monetary position of silver and might lead to reversing this country's silver program

In hearings on the Green bill testimony was presented which included W.P.B. estimates of greatly expanded war uses and essential civilian uses for silver in 1943 and thereafter; a consequent very proper desire on the part of the War Production Board, and the Navy as well, to safeguard all silver supplies irrespective of source; and the statement from industry that 30 million oz. per year from Treasury stocks would be all that non-essential users of silver would expect.

However, all bills concerning this matter failed of enactment before adjournment of the 77th Congress at the year's end.

The failure of the Green bill to become law made little actual difference to the non-essential users of silver, as the bill in its final form would probably have brought them no relief. They were therefore compelled to confine their buying to domestic silver, of which the supplies at the year end were insufficient for their needs. Meanwhile foreign silver, which would have made a welcome supplement, was debarred from non-essential use by a W.P.B. order, and all amounts of current production in excess of priority orders were being accumulated by the Metals Reserve Corp. in expectation of an enlarged war demand.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Kennametal tools. McKenna Metals Co. Bulletin Hf-238.

"Cylindrical Superfinishing." International Machine Tool Corp., Foster Div. Bulletin Hf-410.

Forging presses. Ajax Mfg. Co. Bulletin Ff-105.

Horizontal extrusion presses. Hydropress, Inc. Bulletin Ff-394.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin Ff-132.

Cutting Oils. Cities Service Oil Co. Bulletin Ec-113.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin Ke-118.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin Af-335.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin Ef-360.

Forty different ways to cut machining costs. Continental Machines, Inc. Bulletin Ef-170.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin Kf-230.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin Kf-433.

Convenient, pictorial chart shows abrasive cloth gadgets in a form that will guide users in the proper finishing operation. Behr-Manning Corp. Bulletin Nf-467.

"Hyper-milling", a radical innovation in face-milling of steel. Firth-Sterling Steel Co. Bulletin Lf-177.

Abrasive belt polishing machines. Divine Brothers Co. Bulletin Kf-434.

Cutting oils. Warren Refining & Chemical Co. Bulletin Kf-454.

Photographs and tables on operation of abrasive cutting machines. Andrew C. Campbell Div., American Chain & Cable Co. Bulletin Nf-466.

Newly developed equipment incorporating use of surface coated abrasive belts for producing faster finishes is described in booklet issued by Minnesota Mining & Mfg. Co. Bulletin Ag-470.

FERROUS METALS

New process embodying both chemical and temperature controls for production of low carbon open hearth case carburizing steel is described in bulletin by W. J. Holliday & Co. Bulletin Bg-293.

"100 Years of Peace and War" is title of attractive brochure celebrating 100th birthday of Joseph T. Ryerson & Son, Inc. Bulletin Bg-106.

Enduro stainless steels. Republic Steel Corp. Bulletin Hf-8a.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin Kd-85.

Free Machining Steels. Monarch Steel Co. Bulletin Cd-255.

Tool Steels. Bethlehem Steel Co. Bulletin Ce-76.

Die Steels. Latrobe Electric Steel Co. Bulletin Ld-208.

Enameling iron sheets. Inland Steel Co. Bulletin Ld-295.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin Kd-229.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin Hb-4.

Four Coppco tool steels. Copperweld Steel Co. Bulletin Cf-311.

Simplified method for calculating heat treatment of alloy steels. Peter A. Frasse & Co., Inc. Bulletin Cf-172.

Nitralloy and the Nitriding Process. Nitralloy Corp. Bulletin Df-116.

Information for determining overall heat transfer rates. International Nickel Co. Bulletin Kf-45.

Wall Chart on spark testing tool steels. Carpenter Steel Co. Bulletin Kf-12.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin Kf-429.

Steels. Boker & Co. Bulletin Kf-450.

Cold drawn steels. Wyckoff Drawn Steel Co. Bulletin Kf-99.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin Ox-74.

Saving of stainless steel through use of Pluramelt. Allegheny Ludlum Steel Corp. Bulletin Df-92.

New 60-page data book on molybdenum wrought steels has been issued by Molybdenum Corp. of America. Bulletin Nf-312.

Shop notes on the machining of stainless steels are presented in new 24-page book by Rustless Iron & Steel Corp. Bulletin Nf-169.

NON-FERROUS METALS

Three new bronzes are described in new Ampco Metal, Inc. Bulletin Bg-175.

6th edition of Revere Weights and Data Handbook includes new section giving technical and mill definitions and illustrations of terms used in copper and brass industry. Revere Copper and Brass, Inc. Bulletin Bg-239.

Silver alloy brazing. Handy & Harman. Bulletin Hf-126.

Bronze. Frontier Bronze Corp. Bulletin Kf-455.

Copper Alloys. American Brass Co. Bulletin Kd-89.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 294, 296, 298, 300, 302 and 304.

Metal Progress 7301 Euclid Ave., Cleveland
Send me the literature I have indicated below.

Name .... **Title** ....

Company .... **Address** ....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 7 pages.

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Hf-238	Kf-454	Df-116
Hf-410	Nf-466	Kf-45
Ff-105	Ag-470	Kf-12
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Ff-132	Bg-106	Kf-450
Ec-113	Hf-8a	Kf-99
Ke-118	Kd-85	Ox-74
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Ef-327	Ka-174	Ag-144
Ef-387	Lf-299	Ag-226

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Aluminum alloys for aircraft. Reynolds Metals Co. Bulletin Lf-436.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin Af-337.

"Machining Alcoa Aluminum". Aluminum Co. of America. Bulletin Kf-54.

Features and savings incorporated in die casting equipment of Lester-Phoenix, Inc. Bulletin Kf-437.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin De-307.

Handy, compact reference data on brass and bronze castings. Hammond Brass Works. Bulletin Df-371.

Reference on properties of lead. St. Joseph Lead Co. Bulletin If-415.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

Dowmetal data book. Dow Chemical Co. Bulletin Ec-215.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin Nf-163.

WELDING

Arc Welding. Lincoln Electric Co. Bulletin Ff-10.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

Stud welding equipment designed for ship deck work but fully meeting requirements of many other uses calling for end-welding of steel sections to metal surfaces is described in new leaflet by Hollup Corp., division of National Cylinder Gas Co. Bulletin Bg-331.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin Ff-393.

Electrode quantity and welding time graph. Arcos Corp. Bulletin Ld-191.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin Ge-63.

"Fight-waste" booklet. Air Reduction Sales Co. Bulletin If-69.

Shield Arc electrodes. McKay Co. Bulletin Gf-248.

Sciaky radial portable welder. Sciaky Brothers. Bulletin Kf-425.

Castolin Eutectic Alloys as a substitute for scarce bronze or brass welding rods. Eutectic Welding Alloys Co. Bulletin Lf-301.

Two-stage "Regolator" for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

Speed is increased 20 to 30% and power costs cut one-third with the Flexarc A-C welders described in new booklet by Westinghouse Electric & Mfg. Co. Bulletin Ag-134.

Preheating, welding and normalizing by electrical reaction and induction is described in leaflet by Electric Arc, Inc. Bulletin Ag-468.

Arc welding accessories available through General Electric Co. are illustrated in new Bulletin Lf-60.

New precision welder with the streamlined arc is described in leaflet issued by Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

Arc-welding without preheat in the repair of brass and bronze castings is described in engineering data sheet issued by Ampco Metal, Inc. Bulletin Ag-175.

"Sureweld" protected arc electrodes, in many types and sizes, described in illustrated literature. Hollup Corp., division of National Cylinder Gas Co. Bulletin Ag-331.

TESTING & CONTROL

X-ray crystal analysis apparatus is described and illustrated in new folder by Philips Metalix Corp. Bulletin Bg-471.

New 29-page catalog—Micromax Electric Control—has just been issued by Leeds & Northrup Co. Bulletin Bg-46.

Wheelco Instruments Co. has just issued five new bulletins describing its complete line of industrial indicating, recording and control thermometers. Bulletin Bg-110.

Bristol Co. has issued series of bulletins covering automatic control and recording instruments for industrial furnaces, dryers, kilns and ovens. Bulletin Bg-87.

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin If-401.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

Use Handy Coupon on Page 292 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 292, 296, 298, 300, 302 and 304.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Metallurgical laboratory apparatus. Burrell Technical Supply Co. Bulletin Ff-213.

Tension and compression strains. American Instrument Co. Bulletin Nv-259.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin Hc-6.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin Bf-345.

Modern Polishing. Tracy C. Jarrett. Bulletin De-303.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

Optical Aids. Bausch & Lomb Optical Co. Bulletin Ce-35.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin Hb-180.

Universal enclosed terminal head. Arklay S. Richards Co. Bulletin Ne-330.

Metallographic polishing powder. Conrad Wolff. Bulletin Cf-368.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin Df-377.

8-page leaflet makes a detailed presentation of the Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

Laboratory and industrial electric furnaces manufactured by Cooley Electric Mfg. Corp. are described in new Bulletin Lf-462.

Automatic stress-strain recording is discussed comprehensively and equipment is pictured in new booklet by Baldwin-Southwark Div., Baldwin Locomotive Works. Bulletin Lf-67.

Metallurgical Equipment. Adolph I. Buehler. Bulletin Ke-135.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

Potentiometer temperature indicators. Foxboro Co. Bulletin Ef-21.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin Kf-206.

Pyrovac radiation pyrometer. Bristol Co. Bulletin Kf-87.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

Surface Analyzer. Brush Development Company. Bulletin Kd-288.

Polishing Machine. Cincinnati Electrical Tool Co. Bulletin Ox-97.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin Kc-37.

X-Ray metallurgical laboratory service is described and illustrated in new file folder issued by Claud S. Gordon Co. Bulletin Nf-53.

64-page booklet on the precision control of industrial processes has been issued by Brown Instrument Co. Bulletin Nf-3.

Constant temperature dry-ice cabinet for temperatures from minus 90 deg. to 220 deg. F. is new laboratory instrument described in leaflet by American Instrument Co. Bulletin Ag-259.

Dillon tensile tester and the Dillon dynamometer are described and illustrated in new leaflet issued by W. C. Dillon & Co. Bulletin Ag-466.

HEATING • HEAT TREATMENT

Tempering, annealing, stress-relieving. Leeds & Northrup Co. Bulletin Hf-46.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

Modern electric furnaces for heat treating are described by Harold E. Trent Co. in new Bulletin Lf-461.

New 8-page booklet describes and illustrates gas, oil and electric heat treating and carburizing furnaces of Holcroft & Co. Bulletin Lf-203.

Faster production with Tocco hardening, brazing, annealing and heating machines is set forth in new 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

Kleen-well oil strainers for quench oil cooling systems is described in leaflet by Bell & Gossett Co. Bulletin Lf-287.

Gas cracking unit for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels is described by Hevi-Duty Electric Co. in new Bulletin Lf-44.

Liquid salt baths for carburizing, annealing, reheating, tempering and neutral hardening are described by E. F. Houghton & Co. in new Bulletin Lf-38.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel are described by United Chromium, Inc., in new Bulletin Lf-463.

Annealing and stress-relieving of cartridge cases are discussed by Surface Combustion Corp. in new Bulletin Lf-51.

Method of handling cylinder anhydrous ammonia for metal treaters is comprehensively described and pictured in 12-page booklet by Armour Ammonia Works, division of Armour and Co. Bulletin Lf-443.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin Ff-286.

Heat treating furnaces. Johnston Mfg. Co. Bulletin Ff-155.

Heat treating production. Lindberg Engineering Co. Bulletin Bf-66.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin Ce-302.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

Use Handy Coupon on Page 292 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 292, 294, 298, 300, 302 and 304.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Low pressure oil burners. North American Mfg. Co. Bulletin Na-138.

Industrial Furnaces. W. S. Rockwell Co. Bulletin Kc-34.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin Nc-15.

Heat treatment in electric salt bath furnaces. Ajax Electric Co., Inc. Bulletin If-43.

Modern Shell Furnaces. Mahr Manufacturing Co. Bulletin Bf-5.

Butterfly Valves. R-S Products Corp. Bulletin Bf-234.

Gas-fired Forge Furnaces. Eclipse Fuel Engineering Co. Bulletin Af-226.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

Vertical Furnace. Sentry Co. Bulletin Ne-114.

Conveyor Furnaces. Electric Furnace Co. Bulletin Be-30.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin Ce-219.

Condensed Catalog. American Gas Furnace Co. Bulletin Ff-11.

Convected Air Furnace. Despatch Oven Co. Bulletin Nd-123.

New Electric Furnace. American Electric Furnace Co. Bulletin Gd-2.

Furnace Experience. Flinn & Dreffein Co. Bulletin Bc-82.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin Bb-187.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin Ke-260.

High Temperature Fans. Michiana Products Corp. Bulletin Hb-81.

Turbo-compressors. Spencer Turbine Co. Bulletin Cf-70.

Drycolene. General Electric furnace atmosphere. Bulletin Df-60.

Electric Furnaces for laboratory and production heat treatment. Hoskins Manufacturing Co. Bulletin Cf-24.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

Electric box type and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

Dual-Action quenching oil. Gulf Oil Co. Bulletin Df-360.

Induction heating. Induction Heating Corp. Bulletin Ef-323.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin Ef-386.

Sub-zero equipment for aluminum storage, shrinking of metal parts. Kold-Hold Mfg. Co. Bulletin Kf-399.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin He-41.

New Heat Source, for Heat Treating, Brazing and Melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin Kc-211.

New manual shows many new technical advances — features exclusive, easy-selection charts on gas-burning equipment. National Machine Works. Bulletin Ag-310.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

Flame-type mouth and taper annealing machine for steel cartridge cases is described in new leaflet by Morrison Engineering Corp. Bulletin Nf-305.

No-Carb, a liquid paint for prevention of carburization or decarburization, is described and use illustrated in new leaflet by Park Chemical Co. Bulletin Nf-141.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

Heat treating furnaces. McCann Furnace Co. Bulletin Kf-446.

Furnaces. Tate-Jones Co. Bulletin Kf-447.

Gas-burning equipment. National Machine Works. Bulletin Fe-310.

Furnaces. Vulcan Corp. Bulletin Kf-448.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin Ag-448.

Attractive 16-page illustrated catalog describes furnaces for heat treating ferrous and non-ferrous metals. Despatch Oven Co. Bulletin Ag-123.

War production with standard rated heat treating furnaces is pictured in new bulletin by Surface Combustion. Bulletin Ag-51.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin Ce-75.

Heavy Duty Refractories. Norton Co. Bulletin Ie-88.

Super Refractories catalog. Carborundum Co. Bulletin Ld-57.

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin Ef-218.

Conductivity and heat transfer charts. Johns-Manville. Bulletin Df-100.

Savings in construction time, labor and money with use of the all Ramix bottom for basic open hearth furnaces are shown in new leaflet by Basic Refractories, Inc. Bulletin Nf-192.

Brickseal refractory coating and discussion of why furnace walls break down are presented by Brickseal Refractory Co. Bulletin Ag-469.

FINISHING, PLATING, CLEANING

Nielco Laboratories offers technical data sheet on brass and copper alkali cleaner. Bulletin Bg-472.

Technical and engineering data on Tygon and typical uses, such as tank linings, are presented by United States Stoneware Co. in new Bulletin Lf-356.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment are attractively described in new 24-page catalog by Detroit Rex Products Co. Bulletin Lf-111.

Cleaning Manual. Oakite Products, Inc. Bulletin Hf-296.

Airless Rotoblast. Pangborn Corp. Bulletin Hf-68.

A protective, deep black finish to steel. Heatbath Corp. Bulletin Hf-189.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin Ne-329.

Pickling. Wm. M. Parkin Co. Bulletin Ff-193.

Modern Pickling. The Enthone Co. Bulletin Ff-240.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin Hd-29.

Anodizing and plating equipment. Lasalco, Inc. Bulletin Kf-457.

"Indium and Indium Plating". Indium Corp. of America. Bulletin Df-376.

Degreasers. Phillips Manufacturing Co. Bulletin Nc-254.

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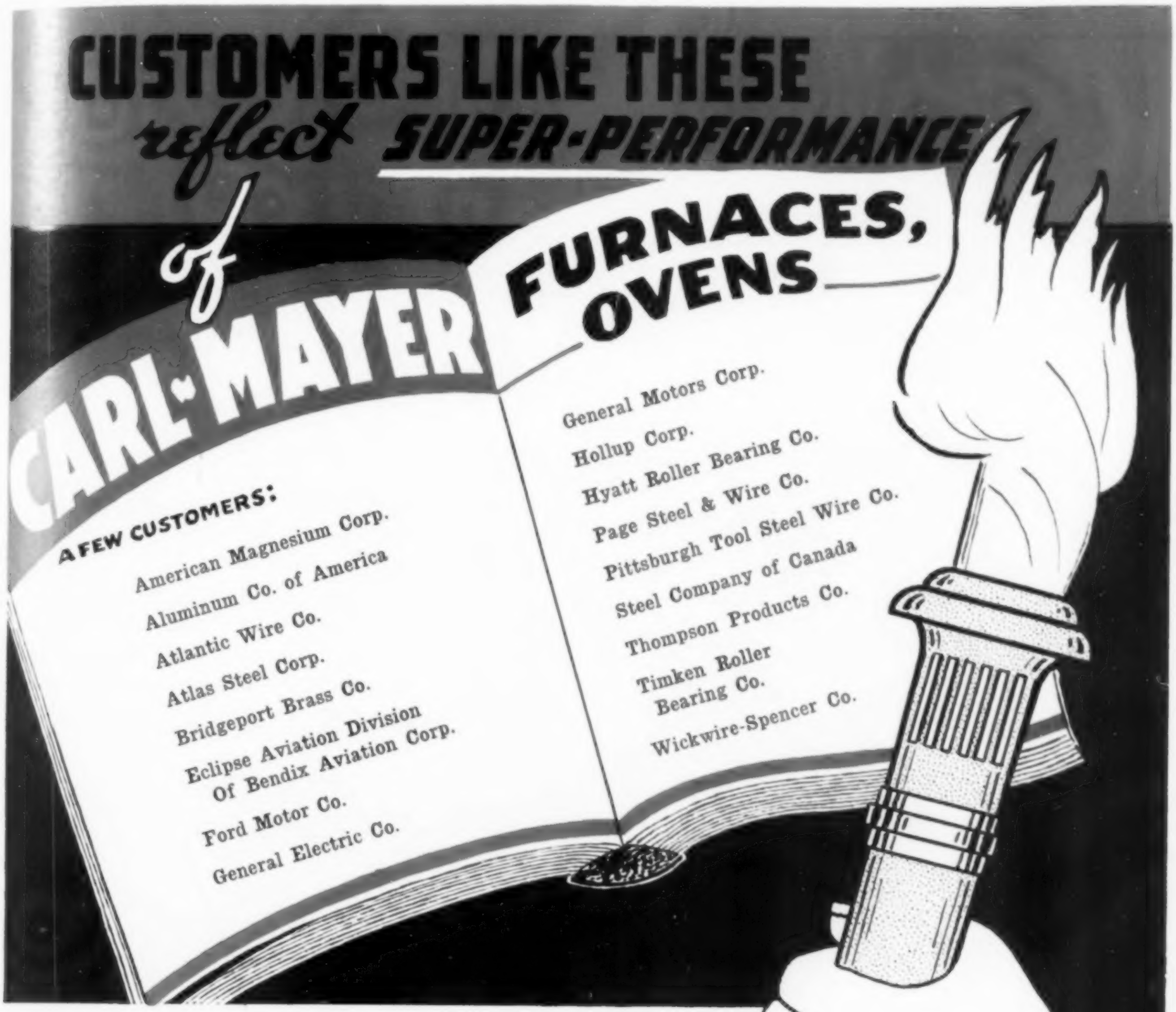

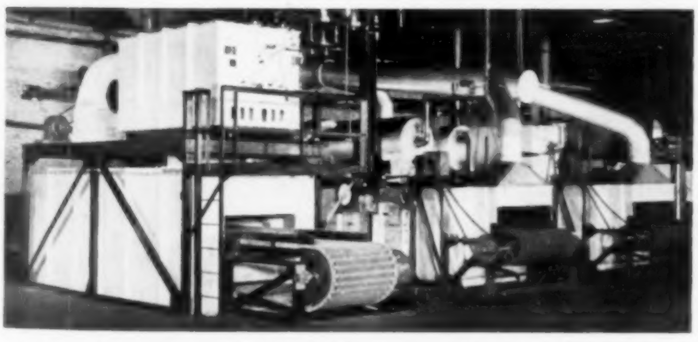

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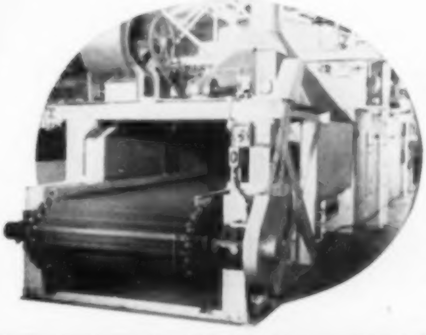

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Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin Kf-456.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin Bf-352.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin Ge-143.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin Gf-256.

Comprehensive new booklet describes the rust inhibiting wax coatings for protection of metal against rust and corrosion developed by S. C. Johnson & Son, Inc. Bulletin Kf-426.

Rust Preventative. Alox Corp. Bulletin Nb-212.

Casting cleaning methods in foundries. N. Ransohoff, Inc. Bulletin Ef-381.

MELTING • CASTING • MILL OPERATIONS

Melting, holding and alloying furnaces are pictured and described in new booklet by Fisher Furnace Co. Bulletin Bg-195.

New pocket size handbook presents compositions and physical properties of most commonly used alloys. Niagara Falls Smelting and Refining Corp. Bulletin Bg-467.

Care of crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin Ff-396.

Rotary positive blower installations in several fields, including smelting, steel mill and foundry. Roots-Connersville Blower Corp. Bulletin Hf-131.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin Bf-16.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.

Ingot Production. Gathmann Engineering Co. Bulletin Ka-13.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin Bf-124.

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin Bf-357.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin Ga-90.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin Hd-271.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin Kf-451.

ENGINEERING • APPLICATIONS • PARTS

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin Kf-430.

Carburizing Boxes. Pressed Steel Co. Bulletin Ce-269.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin Bf-233.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin Ld-32.

Meehanite Castings. Meehanite Research Institute. Bulletin Bf-165.

Ledaloyl, self-lubricating bearings. Johnson Bronze Co. Bulletin Af-237.

Metal Baskets. W. S. Tyler Co. Bulletin Bf-359.

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Steel Castings. Chicago Steel Foundry Co. Bulletin He-184.

Heat Resisting Alloys. General Alloys Co. Bulletin D-17.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin Bb-84.

Metal Powders. Metals Disintegrating Co. Bulletin Ec-208a.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin Cf-370.

Handy wire data chart. Callite Tungsten Corp. Bulletin Ef-327.

Corrosion and heat resistant alloy. Lebanon Steel Foundry. Bulletin Ef-387.

Lead-base metals. Magnolia Metal Co. Bulletin Kf-422.

Comprehensive, pictorial description of wide range of applications where Velvetouch Bimetallic friction material may be installed is described in new plastic-bound booklet by the S. K. Wellman Co. Bulletin Kf-423.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin La-23.

Duriron. A new bulletin on steam jets, ejectors, tank outlets and spray nozzles. Duriron Co. Bulletin Gc-152.

Heat and corrosion-resisting castings. Standard Alloys Co., Inc. Bulletin Ke-151.

Centrifugal Iron. Shenango-Penn Mold Co. Bulletin Ka-174.

Industrial baskets, crates, trays and fixtures are described by Rolock, Inc., in new Bulletin Lf-299.

Standard and special shapes of seamless steel tubing are described and pictured in new leaflet by Summerill Tubing Co. Bulletin Lf-108.

New 12-page booklet describes background, manufacture and typical applications of Tungsten. Cleveland Tungsten, Inc. Bulletin Lf-460.

Handling baskets for heat treating, washing, dipping, degreasing, etc., are shown in new leaflets issued by Union Steel Products Co. Bulletin Lf-459.

Instrument Specialties Co. has issued "Better Brush Springs", reference leaflet showing how "Microprocessed" beryllium copper brush springs have answered demands and includes data and formulae for spring design. Bulletin Nf-468.

Conversion from several types of scarce metals to malleable iron is described and illustrated in new booklet by Lake City Malleable Co. Bulletin Nf-469.

Cooper standard alloys, its services and facilities are described in new bulletin. Cooper Alloy Foundry Co. Bulletin Ag-144.

Seamless pressed steel heat treating containers. Eclipse Fuel Engineering Co. Bulletin Ag-226.

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